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# Phytopathology

## Official Organ of the American Phytopathological Society

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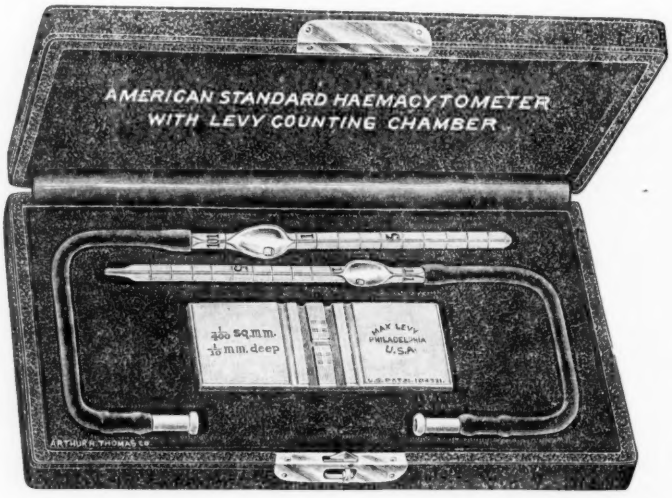


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PHYTOPATHOLOGY

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# SOME OF THE BROADER PHYTOPATHOLOGICAL PROBLEMS IN THEIR RELATION TO FOREIGN SEED AND PLANT INTRODUCTION[1]

BEVERLY T. GALLOWAY

*Plant Pathologist, Office of Foreign Seed and Plant Introduction, Bureau of Plant Industry, United States Department of Agriculture*

For nearly a quarter of a century the study of plant pathology in this country was without very broad or definite aims or objects. This was to be expected in a new work and in a new country where innumerable immediate problems were pressing with few men to handle them and the training of others difficult. The immediate needs of the diseased plants already with us kept our hands full, hence it was not practicable to give much attention to the broader questions of growing crops in such fashion that they would be protected from disease or else surrounded or provided with an environment that would tend to keep them in health.

Within the last decade the medical profession has made wonderful progress in organized, coordinated sanitation, with the result that there has been a noticeable falling off in the death rate, especially where public and community effort have been put into effect. Not only has great progress been made in broad questions of sanitation, but marked advances have been made in hygiene, with the result that many diseases formerly accepted as inevitable burdens are very much reduced and in some cases entirely prevented. Marked advances have also been made in the handling of animal diseases, and in this field we have a striking example of the far-reaching effect and value of a unified, constructive, conservative policy in meeting problems such as have to do with disease control or disease prevention.

Diseases of neither animals nor plants respect State lines or other arbitrary boundaries, hence they can be met best by some proper, responsible

[1] Presented at the meeting of the Phytopathological Seminar, Washington, D. C., December 21, 1917.

form of centralized control. Fortunately the organic act creating the Bureau of Animal Industry of the U. S. Department of Agriculture gave it power that is not possessed even by the Governmental agencies responsible for the control and prevention of diseases of man. The work of the Bureau shows that the broad powers with which it is invested have not been abused, and that in a number of instances they have been the means of safeguarding the country against gigantic losses that would undoubtedly have resulted through divided authority and responsibility.

The first step in the direction of similar broad powers for controlling diseases and other enemies of plants was the Plant Quarantine Act. This measure was a compromise, but was unquestionably the best that could be obtained at the time. It must be borne in mind that the act creating the Bureau of Animal Industry became a law more than thirty years ago, when very little attention was given to questions of relationships and interrelationships between the Federal Government and the various States. On the other hand the Plant Quarantine Act came into being when the country was rife with probably one of the most bitter controversies in its history as to whether the natural resources of the land should continue to be exploited by the few or whether they should be regarded as the property of the whole people and as such administered and controlled by the nation. At this time every movement looking toward anything like centralized control was heralded as another step in the direction of national domination and therefore was not to be tolerated.

Since the passage of the Plant Quarantine Act many things have come to pass that have molded public sentiment to the end that broader Federal control would now be looked upon as a relief from the varying and almost prohibitive conflicting actions resulting from the widely different laws of the States. Business men are finding that restrictive and regulatory laws will be enacted by the States in any event and that it is easier to do an interstate business under one law than to attempt to do it under a dozen different laws of as many different States. It would appear, therefore, that the time is approaching when a broader view, looking toward broader action in matters relating to the control of diseases and insect pests of plants, will develop—a view that will include in a definitized, coordinated way not only matters involving certain regulations and restrictions, but broader questions of national as well as international plant sanitation and plant hygiene. Our object in bringing these matters forward now is to have them serve as a sort of background or introduction to the main issues we wish to present at this time.

The Office of Foreign Seed and Plant Introduction has now been in operation nearly twenty years. During that time it has developed an organized system of foreign agricultural explorations; definite plans of

introducing, propagating, and testing seeds and plants; and an elaborate scheme of collaboration and cooperation with scientific workers and private growers. The Office has also become a clearing house or medium of exchange for all branches of the Department of Agriculture and for the State experiment stations and other institutions in matters relating to the securing of seeds and plants from foreign countries and for forwarding to workers abroad plant materials that may be of value to them. Furthermore the Office has five field stations, where many plants are received, propagated, tested, and distributed, and maintains in Washington an inspection and quarantine branch for the use of the Federal Horticultural Board and other offices of the Department, the State experiment stations, scientific investigators, and others.

From this brief outline of the activities of the Office of Foreign Seed and Plant Introduction it will be seen that they involve some broad problems in phytopathology. Conditions are such in fact that the Office must necessarily do a considerable amount of pioneer work, and it must also serve as a sort of agency through which and, I might say, based upon which the inspectors of the Federal Horticultural Board very properly make tests and experiments for the benefit of the public at large. Briefly, in other words, the Office of Foreign Seed and Plant Introduction, with the object of building up American agriculture, is bringing into this country many kinds of seeds and plants from widely scattered regions of the earth; is growing, testing, propagating, and distributing these plants at five field stations; and is having the material grown by several thousand cooperators and collaborators.

Public sentiment develops slowly in such matters and a long time will elapse before it is educated sufficiently to accept and put into practice the things the Office is now doing and planning to do in the way of meeting some of the more pressing and vital phytopathological problems. However, we regard it as one of the legitimate functions of the Office to so conduct this phase of its work and to so establish relationships with the Federal Horticultural Board that the results will be broadly educational in the sense that any and all accomplishments in safeguarding and protecting our crops are educational.

The wastage of food products in this country from the attacks of insects and diseases has been so prominently before the people that it is needless to refer to it in detail here. In the past we have accepted these wastes as a part of our prodigal methods and practices, but we are rapidly learning that our prodigal days are over. We must take stock and gird ourselves for the coming activities for supplying the world with food.

In a way the work involved in the protection of new plant introductions is of a kind that will probably need to be done at no distant day for the

country at large. Much of it is pioneering and therefore should be conducted while in this stage by the Department of Agriculture and by other public institutions.

In the work now under way and planned certain principles are recognized and these may be briefly stated as follows:

1. The work is international. We can no longer view any of the broad phytopathological problems as local. They are world-wide and require not only world-wide consideration and study from the phytopathological standpoint, but also world-wide consideration and study from the standpoint of economics.

2. Regulatory and restrictive measures must be regarded as palliative at best. We can not hope to permanently check or retard through them the inevitable distribution and spread of destructive crop insects or injurious plant diseases. To be most effective such measures must be internationalized, as by this means checking or retardation can be considerably prolonged. If properly administered, regulatory or restrictive measures of any kind are worthy of the best support, as experience has shown that in the majority of cases they are highly profitable.

3. Plant hygiene, or a systematic, organized, coordinated study of crops in their relation to environment, offers the broadest field for research and applied science. Just as the science of preventive medicine is supplanting the more or less empirical practices of the old-school practitioners, so must the science of plant hygiene supplant many of the prevailing practices in plant pathology.

Let us now briefly consider the principles above outlined in their relation to the work of foreign seed and plant introduction.

From December 1, 1916, to December 1, 1917, approximately 3500 lots of plants, seeds, roots, cuttings, scions, and bud sticks were received from all parts of the world. Three-fourths of the material was foreign, while the other fourth was domestic, destined for foreign countries, largely as a matter of international exchange. The phytopathological problems involved in this work are necessarily international, and if they are international as affecting the very limited activities of the Office and the comparatively limited field that it covers, they are preeminently so when we come to regard the world-wide movement of plants and plant products in commerce.

The problem, then, is to make use of these plant materials to the fullest advantage, to free them so far as practicable from existent and potential enemies, to disturb as little as possible the economic balance of the particular plant or crop in the general scheme of crop production and crop economics, and to insure just and reasonable action toward those agencies, foreign and domestic, with which we have to deal. Anything in the na-

ture of National or International phytopathological work undertaken without these broad objects in mind is destined to limited usefulness, for sooner or later it will be blocked by virtue of its inert weaknesses.

Before some of these complicated problems can be taken up a large number of preliminary activities must be carried on in order to lay the ground work for the broader questions. First among these may be mentioned the need of phytopathological surveys—local, national, and international. Such surveys properly conducted and coordinated, would be of great value in all matters having to do with the handling of plants and plant products. They would serve as a reliable and intelligent guide in many matters having to do with the shaping of policies, the enactment of laws, and the developing of proper public sentiment. It is too much to expect such surveys to be inaugurated all at once. An evolutionary process will be necessary. It is fortunate that we are developing a plant-disease survey in this country along national lines. This work is already showing its value, and the proper interpretation and application of the results secured may be the means of developing similar action in other countries which will eventually lead to a broad coordination of effort.

In the comparatively limited work of foreign seed and plant introduction we are already reaching a point where the need is strongly felt for more definite, advanced knowledge of the enemies, potential and otherwise, that we are likely to have on our hands when we undertake any general agricultural explorations. In fact the question may well be raised whether the risk is not too great to warrant general agricultural explorations, accompanied by a promiscuous general seed and plant introduction, with no other check than what may be secured through careful, yet necessarily imperfect examinations after the plant material is here. Agricultural explorations involving seed and plant introduction is an important function of the Government, but the time would seem to be approaching when these explorations should be back-grounded by careful phytopathological surveys or else the phytopathological features of the work should be handled at the time of the explorations.

With regard to the second principle, namely that regulatory and restrictive measures must be regarded as palliative, we apply these measures probably nore intensively in the work of foreign seed and plant introduction than could probably be done on a broad commercial scale, and yet there is always the element of risk. We work on the theory that every precaution must be taken, and so far we must say, to the credit of those responsible for the work, that no serious or dangerous crop enemy has slipped by.

In meeting such problems we are greatly handicapped by lack of knowledge on some very vital matters. Take for example the question of the

proper treatment of the great variety of seed that passes through our hands. It is surprising how little we know regarding the treatment of seed in order to render it phytopathologically safe and still have it retain some semblance of agricultural or horticultural value. This is one of the matters upon which it is not safe to generalize. Our knowledge of the potential dangers from seed as a carrier of disease is extremely limited. When we come to apply existing practices in seed treatments we find that in a great measure they are more or less empirical. Here, it would appear, is a very important field for research and one which would yield results of much value in determining the proper basis for action in the development of regulatory or restrictive measures so far as seed is concerned.

We have briefly referred to the difficulties of proper action in regulatory matters, owing to conflicting and confusing statutes enacted by the States and the varying interpretations of these statutes by the officers responsible for their enforcement. Because of this conflict and confusion the Office of Foreign Seed and Plant Introduction is already beginning to experience difficulty in distributing its plant material, and if this is true in the case of a Government agency, exercising as it does through the Federal Horticultural Board what might be termed extreme precautionary and restrictive measures, commercial agencies handling large interstate shipments must encounter even greater difficulties.

It must be understood that we are not advocating any diminution of proper restrictive work. Such work, should be developed and conducted, we believe, with proper regard to legitimate business operations and common-sense business methods.

It is probably too much to expect anything approaching centralized control of all these regulatory matters in this country, although rapid strides in that direction have been made during the past year. There is need, however, for some sort of Government coordinating agency or clearing house through which and by which all these agencies officially engaged in regulatory work affecting plants might be brought into unison without impairing their freedom of action or their integrity.

In regulatory matters affecting foods and food products such action has already been taken and the results have been very satisfactory. An office of cooperation in regulatory matters has been established in the Bureau of Chemistry, and for the last three to four years this office has very quietly, but very effectively, brought about many advances in unison of effort on the part of all the State and other agencies charged with the enforcement of food laws. The office acts as a clearing house, and largely through the personality of the officer in charge the state officers and others have established a system of exchange of views and information which has greatly simplified food control measures in this country. It might be practicable

for the Federal Horticultural Board to so expand its activities as to develop such an office or this work might be developed out of the Plant Disease Survey.

We now come to the third and most important of our principles, namely plant hygiene, or a systematic, coordinated study of crops in their relation to environment. Any work attempted in this field, in so far as it relates to foreign seed and plant introduction, must necessarily be more or less fragmentary. We must confine our efforts to the things we are working with, and these are so numerous and varied that we can not hope to do more than touch the surface. We never realize how little we know about plants until some particular kind of plant is singled out and studied from all angles. This means practically a life work for any man.

Theoretically, plants should be free from insects and diseases. If environment were perfect and the plant's ability to respond perfect, perfect health would result. This of course is out of the question, but there is no reason why we should not strive to approach the ideal. The nearest approach to it is to be found where many of the essential factors are under the control of the grower, as in the case of plants grown under glass. Did the grower of these plants have to depend on and follow the methods and practices of the orchardist he would, in all likelihood, soon have to go out of business. One is a hygienist par excellence, the other a plant doctor by virtue of the fact that it is the only thing he can be under the circumstances.

Many of the things the high-grade greenhouse man does he does subconsciously. These things are in large part not measurable, but nevertheless they are often the limiting factors in questions of health and disease. A houseful of lettuce may be growing splendidly and every head in firstclass condition. A desire on the part of the grower to force his crop or a lack of knowledge as to consequences may induce him to take a chance and run his night temperature higher than it should be. If the lettuce is growing in a certain type of soil he may be able to carry the higher night temperature for a short time, or if the weather is clear and bright he may also be able to do it, but if the soil is cold, and in this one word we include a whole series of physical and biological factors, he produces by his night forcing a tissue structure that may collapse at the first strain put upon it, which is usually a bright day following a cloudy spell of weather. Collapse is hardly the proper word, for the injury may not be noticeable for some time, but it is sufficient to open the way for the attacks of Botrytis and other fungi, which to the casual observer appear to be the prime causes of the trouble.

We have sketched here just a few of the high points in a very complicated series of phenomena. In the work of foreign seed and plant intro-

duction we are interested in plant hygiene, in that we endeavor to bring in only healthy plants and, when they are in, to keep them healthy. Such work is more or less local, but it is hoped that it will result in securing facts that will eventually be helpful in a broad way.

There are broad phases of plant hygiene, however, that must be developed through combined effort and coordinated action on the part of pathologists and others. It would seem desirable to inaugurate systematic, world-wide studies of the botanical relationships of some of our principal crop plants. Such studies will not only furnish a foundation for intelligent action with regard to the economic uses of plants, but should develop facts that may aid in protecting our crops against possible potential enemies and also give us valuable aid in supplying material with which we can fight plant enemies that we already have. An example of what can be done in this field is found in the work of Mr. Walter T. Swingle on citrus. Doubtless even now there are enemies lurking on obscure, wild, or little-known plants in many parts of the world which need readjustments or maladjustments only in environment to make them serious pests.

Just now there is a good deal of interest in the jujube (*Zizyphus jujuba*) as a possible new fruit for many parts of the South and Southwest. The Office of Foreign Seed and Plant Introduction has been working on this fruit for a number of years. Stocks and established varieties have been introduced from the Orient and are now being grown and propagated at the field station at Chico, California, but more material will have to be brought in. Here is a potential new industry. What are the kin and near kin of the jujube? Are there enemies, existent or potential, that should be guarded against? Are there relationships that may be useful in broadening the range of the plant here or in adapting it to conditions under which otherwise it might not prosper?

Out of a study of plant relationships will come many subsidiary problems, such as the securing of disease-resistant species and types and their use in breeding purposes and for stocks. The whole relation of stocks to plant hygiene is a vital one and must play an important part in future plans in preventing the enormous wastes in many of our valuable fruit crops.

Sanitation as a phase of hygiene must be considered. The removal of many of the causes of disease is practicable, but there is a vast amount of educational work to be done before effective action can be secured in this field. We have the problem of sanitation and sanitary practices at our field stations, and when we consider all the other things the men at these stations have to do the wonder is that so much is accomplished along this line.

It is a rare thing to find a practical plant grower who appreciates what

cleanliness in a pathological sense means, and yet success in growing a crop often hinges on the proper application of this very point.

The gradual shifting of plant industries from one region to another offers very interesting material for study. While the causes may be grounded in economic adjustments these adjustments are frequently made necessary by failure to appreciate or properly understand plant sanitation in a broad sense. Not long since I was told by one of the largest nurserymen on the Pacific Coast that he could no longer afford to buy land for nursery work. Fighting certain cumulative soil pests, such as crown gall, nematodes, and gummosis, cost so much that it was cheaper to rent land and move on every few years. This practice can not, of course, be continued indefinitely. Means must be found for correcting the difficulties in other ways.

While a great deal of beneficial sanitation is within the power of the individual, the State must be brought to see the importance of the matter if far-reaching results are to be secured. The State never moves in such matters until there is a ground swell of public opinion behind it, and this ground swell can best be created by bringing to the individual grower the importance and value of sanitary practices in all his work.

There is a phase of crop hygiene that so far as we are aware has received little attention as yet in this or any other country. For want of a better title we might call it plant-disease detection. It would be in the nature of crop insurance, It would differ from a plant disease survey in that the disease would be detected before it had assumed sufficient importance to be surveyed. We can apply this work to our field stations, but it should be applied to the country at large. The work presupposes central directive power. It would be national. Is it not reasonable to believe that were a properly organized corps of men engaged in the field in this kind of work many of our most serious and widespread pests would have been discovered in their incipient stages and could have then been stamped out?

The State is slow to move in such matters. It is rather prone to wait until things happen and then act. Public sentiment was a long time in crystallizing to the extent that such precautionary measures were made practicable in connection with some of the most serious diseases of man, and it has not yet reached the point where it is willing to require the State to undertake this kind of work with the diseases of our domestic animals. There is no adequate force of men constantly on the lookout for foot-and-mouth disease. Such a force of men might cost the Government fifty to sixty thousand dollars a year, but if the disease was discovered and stamped out in its incipient stages it would be money well spent.

Finally, we would like to speak briefly on what appears to be two very

broad fields of usefulness in plant hygiene. The first has to do with the relation of weather to outbreaks of plant diseases and the relation of weather to plant-disease control, and the second is concerned with soil and fertilizer requirements as affecting pathological phenomena. We know that the weather plays a most vital part in all crop production. We do not want to discuss this broad subject now. Suffice it to say that there would appear to be enough data and experience to warrant attempts at plant-disease-outbreak forecasting in a limited way at first, same to be increased as knowledge is gained. This would need to be taken up by men trained not only in pathology, but also possessed of broad knowledge of crops, crop production, and crop economics.

Coupled with crop-disease forecasting would be timely warnings as to action in preventive measures. In a number of the midwestern, lake region, and northern Atlantic States the movement of cyclonic areas is so well defined, especially during the spring, early summer, and fall that it would appear feasible to use them as a basis for timely warnings as to when to spray or not to spray plants. I believe such use is already being made of weather data in a limited way. Our point is that it should be developed into a broad National service.

As to the soil and fertilizer requirements in their relation to plant hygiene, we have many striking examples of the broadness of the field. The losses through plant diseases due to maladjustments of crops to soils and through malnutrition, the result of misuse of so-called plant foods, are strikingly large. Can these losses be met or mitigated through broad phytopathological studies? We believe that they can, but to get the large, essential facts and to properly group them so that they can be used in a broad way will require unity of action.

We have here in the eastern United States and also extending into many States of the South a vast area of soil capable of producing immense quantities of food under proper agricultural management. I refer to the acid lands of the Coastal Plain Region. For centuries we have been handling this land and cropping it without due regard to the fact that many of the introduced plants are out of place there. It would seem that with our present knowledge we might do much toward a proper adjustment of crops to soil and thereby greatly increase the production of the region.

One of the field stations of the Office of Foreign Seed and Plant Introduction is located at Brooksville, Florida. This station was established primarily as a place to grow, test, and propagate bamboos. It is in a section, such as may be found in many parts of the South, in which numerous crop enterprises have been launched in times past and most of which have failed, about the only ones persisting being those that are not seriously affected by the ravages of nematodes. Corn, velvet beans, and several

promising grasses may eventually make live-stock production, especially the raising of hogs, a profitable business.

Here we find ourselves asking other far-reaching questions. Can we look forward to a successful live-stock agriculture in certain parts of the South if we have to depend wholly upon the crops produced there? May not calcium be the limiting factor in the successful raising of certain kinds of live stock in this region, and can calcium be supplied to the plants in such quantity and form as to give them the maximum development and supply the necessary cell-building materials? We may be overstepping the bounds of phytopathology when we open up such problems, but after all we are seeking the truth. Are we to follow the rule of the Chinese and secure truth only through century-long trials and retrials, or are we to secure it through the channels of science, which after all recognize no hard and fast lines between those who labor in its fields?

# THE ALTERNARIA LEAF-SPOT OF COTTON

R. C. Faulwetter

With Three Figures in the Text

A disease of cotton leaves, due to a species of Alternaria, is common in South Carolina and very probably in other of the cotton-growing states. So far as is known it has never been described, though the disease was recognized and some studies made by Beal of the Mississippi Agricultural College in 1914. Investigation of the subject was undertaken by the writer because of its relation to the angular leaf-spot, a disease which has been under close observation for some time.

The fungus causing the disease is not a virulent parasite when compared to other species of the same genus, *A. panax* Whetzel,[1] for instance, which is said to be able to destroy entire gardens of ginseng. The lesions of this disease of cotton arise in and spread from earlier injuries of the leaf in the great majority of instances. In the early part of the summer these are most frequently the angular spots caused by *Bacterium malvacearum* Smith. Other injuries may serve for this purpose, and occasionally the disease develops where no previous wound can be detected.

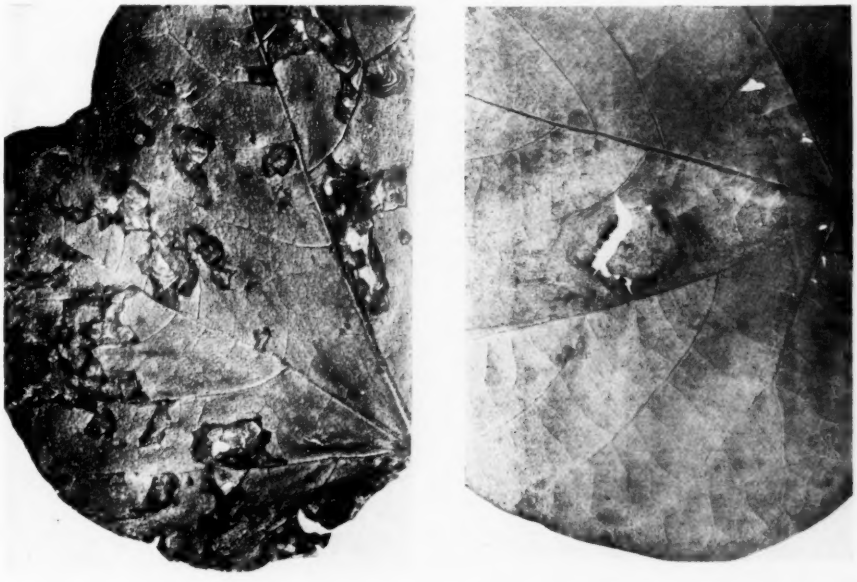
The Alternaria spot when developing from a bacterial spot first appears at one side as a pale green area, having an indefinite and irregular margin. As this area increases in size the color of the older portion becomes straw-yellow and finally rusty brown. By this time the spot contains a number of irregular concentric zones, resembling those diseases of other plants ascribed to species of Macrosporium and Alternaria (fig. 1). The largest spots formed in this way have a breadth of 1.5 to 2 cm. and are usually of irregular shape with nearly equal breadth and length. It very often happens that the fungus grows outward from the bacterial spot in all directions and finally surrounds the former. In such cases the definitely angular spot may be detected in its center by holding the leaf to the light. The bacterial spot is translucent while the fungous spot is opaque.

The same dark brown, papery spot is common in the region of red spider injuries upon the leaves (fig. 2). The principal point of difference in the two types of spots lies in the fewer and less conspicuous zones in the latter case. When examined with a hand lens the zones are easily seen, but usually lie close to the margin. Entomologists agree that

[1] Whetzel, H. H. and Rosenbaum, J. The diseases of ginseng and their control. U. S. Dept. Agr., Bur. Plant Industry Bul. 250: 9–17, 1912.

this condition is not caused by the spiders alone. Such areas are very common in the angles of the main ribs and often spread over a large part of a sector of a leaf.

During the latter part of the summer cases of the disease have been found in which neither angular leaf-spot, red spider or other injuries seem to be present. It is difficult to determine conclusively the necessity of such wounds for the entrance of the fungus, but judging from the material examined it seems probable that conditions exist under which the fungus is able to invade uninjured tissues. Whether these condi-



(1) (2)

FIG. 1. ALTERNARIA LEAF-SPOT FOLLOWING ANGULAR LEAF-SPOT
FIG. 2. ALTERNARIA LEAF-SPOT IN THE CENTER OF RED SPIDER INJURIES

tions involve the physiology of the host or parasite, or the external environment, the writer is not prepared to say.

Water mounts of scrapings from the surfaces of these spots always contain Alternaria-like spores (fig. 3 left). In such mounts they have only been found singly. Examination of the surfaces by means of a binocular microscope show the spores frequently in chains of two. On material collected during a particularly rainy period and examined immediately, chains of spores were found containing three and four each. The surfaces of petri dish cultures also show such chains, though this evidence is less important than that found under more natural conditions.

The fungus is easily cultivated from spores and tissue-plantings upon potato agar. The mycelium when grown upon this medium is at first white, turning blue at the center, soon becoming entirely bluish black. The medium beneath an agar-slant culture appears to be stained, but when the mycelial felt is removed it is seen that this is not the case.

Upon the infected areas, the conidiophores are erect or nearly so, usually simple but occasionally branched; fuscus brown; septate, cells 6 to 9 $\mu$ long by 3 to 6 $\mu$ wide; they arise singly, rarely in pairs, moderate-

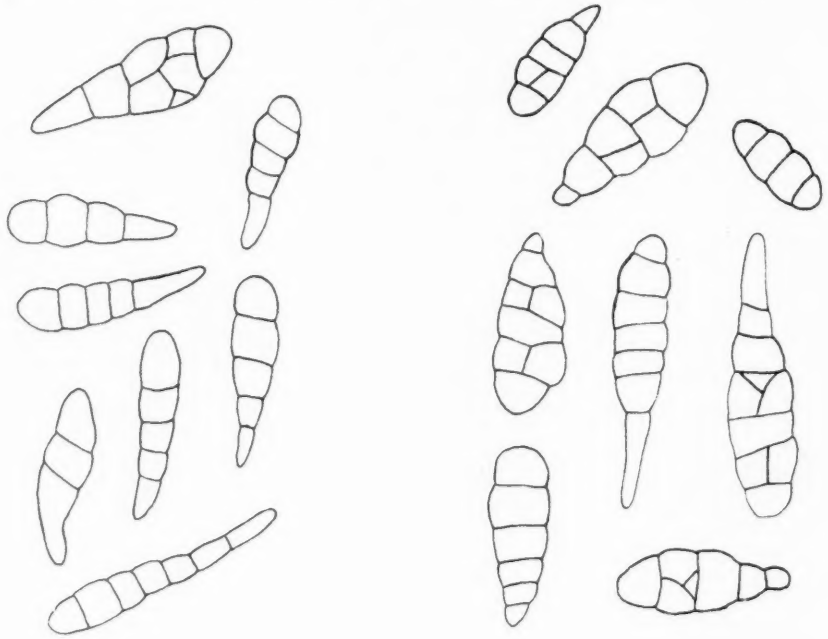


FIG. 3. SPORES OF THE ALTERNARIA CAUSING A LEAF-SPOT OF COTTON
At the left, spores from the lesions. At the right, spores from potato-agar culture

ly sparse in scattered areas, never forming a superficial velvet, amphigenous, 15 to 60 $\mu$ long. The conidia are produced at the apex of the conidiophores or their branches, singly or in catenulate pairs, under humid conditions in chains of three or four; obclavate, more or less acutely pointed, often beaked; beak never longer than the conidium, often septate, not constricted at the septa, hyaline or nearly so. Conidia are olivaceous, septate in cross and longitudinal planes, slightly constricted at the septae, 22 to 35 by 6 to 13 $\mu$ (fig. 3).

Inoculations have been made with spore suspensions sprayed upon

the top and bottom sides of the leaves, by placing small bits of the mycelium upon the top and bottom sides of the uninjured leaves, upon others on the angular bacterial spots, and even by applying the mycelium to needle pricks in the leaves. No infections resulted from this work, and

TABLE 1

*Results of inoculations of cotton leaves by Alternaria sp. August 18, 1917*

| CULTURE NO. | INOCULATION OF HEALTHY LEAVES | | | INOCULATION THROUGH BACTERIAL SPOTS | | |
|---|---|---|---|---|---|---|
| | Leaf | Inoculations | Infections | Leaf | Inoculations | Infections |
| Alternaria no. 1 | 1 | 5 | 5 | 1 | 10 | 10 |
| | 2 | 6 | 6 | 2 | 6 | 6 |
| | 3 | 5 | 5 | 3 | 6 | 6 |
| | 4 | 5 | 5 | 4 | 3 | 3 |
| | | | | 5 | 4 | 4 |
| | | | | 6 | 3 | 3 |
| Alternaria no. 2 | 1 | 5 | 5 | 1 | 6 | 6 |
| | 2 | 6 | 6 | 2 | 10 | 10 |
| | | | | 3 | 7 | 7 |
| | | | | 4 | 5 | 5 |
| | | | | 5 | 4 | 4 |
| Alternaria no. 3 | 1 | 3 | 3 | 1 | 11 | 11 |
| | 2 | 12 | 12 | 2 | 2 | 2 |
| | 3 | 6 | 6 | 3 | 2 | 2 |
| | | | | 4 | 3 | 3 |
| | | | | 5 | 5 | 5 |
| | | | | 6 | 5 | 5 |
| Alternaria no. 5 | 1 | 7 | 0 | 1 | 8 | 8 |
| | 2 | 12 | 0 | 2 | 9 | 5 |
| | 3 | 5 | 0 | 3 | 3 | 3 |
| | | | | 4 | 2 | 2 |
| | | | | 5 | 10 | 10 |
| | | | | 6 | 6 | 0 |
| | | | | 7 | 9 | 0 |
| Total | 12 | 77 | 53 | 24 | 139 | 120 |
| Per cent | | | 69 | | | 86 |

finally relatively large pieces (5 to 10 mm. square) of petri dish cultures were placed upon the under side of leaves. Uniform success resulted from this method on'y when rapid desiccation of the mycelium did not take place.

The results of the preliminary experiment in which this fact was de-

termined are tabulated on page 101 (table 1). The organism was applied to the lower side of the bacteria' spots on leaves thus infected, and in several places upon the lower side of uninjured leaves.

It had been the plan of the experiment to use the inoculations of healthy leaves as controls of those through the bacterial spots on other leaves. It seemed most probable at that time, that infection only took place in this way, but when this conclusion was disproved, the work was repeated with healthy uninoculated leaves as controls. The cause of the few infections by Alternaria culture no. 5 has not been explained, though it was probably due to some mechanical error in manipulation, since later work with the same organism gave more successful results. Tissue plantings from several of these spots produced by artificial inoculation were made on potato agar and in each case fungi developed which were identical with those used for the inoculations.

Cultural studies of these organisms were made on potato agar containing 2 per cent agar and on several synthetic media containing various sugars and 1.2 per cent agar. It happened that only those inoculations in which the latter cultures were used gave successful results. It is not probable that the composition of the medium could be the cause of the difference especially since inoculations with small bits of the cultures on the sugar media had given a low percentage of infections.

A comprehensive experiment, covering all phases of the problem presented, was arranged. In each series, fifty healthy leaves were used as controls. Fifty healthy leaves were inoculated in one or more places as were fifty others having a few bacterial spots, and all were covered by manila paper bags to prevent natural inoculation during the period of the experiment. Small bits of potato-agar culture (less than 5 mm. square) small bits of sugar-agar cultures, large bits of potato-agar cultures and large bits of sugar-agar cultures were each used in a series of inoculations as outlined above. The last was repeated with three strains of the fungus. While fifty leaves were used for each test, the wind injured many of them, reducing the number to 23 in one case and less in others, though under these circumstances sufficient data remain upon which tenable conclusions can be based. The results of the experiment are shown in table 2.

The seeming large amount of disease upon the bagged checks is due in part to the unfavorable conditions for development arising in the bags. Upon these leaves, spots of any sort which resembled the Alternaria in its various phases were recorded, while results of the inoculation were only marked "positive" when the remains of the inoculum could be discerned upon the under side of the diseased area. The natural spots similar to those upon the control leaves were not confused with

inoculations and included in the results, though it may appear that the controls were worthless from an experimental standpoint.

The greater susceptibility through the angular leaf-spots as compared to healthy tissues is well shown by the results of the series 1 to 4. The conditions of these experiments were not favorable for infection as is shown by the low percentage of healthy leaves infected. Under those identical conditions a much greater infection took place through the bacterial spots.

TABLE 2

*Inoculation of cotton leaves by Alternaria sp. August 28 to September 3, 1917*

| SERIES | CONTROLS | | HEALTHY LEAVES | | | BACTERIAL SPOTTED LEAVES | | |
|---|---|---|---|---|---|---|---|---|
| | Leaves | No. | Leaves | Inoculations | Infections | Leaves | Inoculations | Infections |
| 1. Small bits of potato-agar culture. Alternaria No. 1. | 4 | 10 | 41 | 66 | 2 | 32 | 43 | 3 |
| 2. Small bits of sugar-agar culture. Alternaria No. 1. | 30 | 3 | 36 | 67 | 3 | 23 | 29 | 7 |
| 3. Small bits of sugar-agar culture. Alternaria No. 2. | | | 33 | 38 | 5 | | | |
| 4. Large bits of potato-agar culture. Alternaria No. 1. | 42 | 8 | 33 | 33 | 1 | 27 | 27 | 17 |
| Total | | | 143 | 204 | 11 | 82 | 99 | 27 |
| Per cent | | | | | 4 | | | 27 |
| 5. Large bits of sugar-agar culture. Alternaria No. 1. | 47 | 5 | 39 | 42 | 42 | 26 | 26 | 25 |
| 6. Large bits of sugar-agar culture. Alternaria No. 2. | 38 | 1 | 39 | 39 | 33 | 37 | 37 | 34 |
| 7. Large bits of sugar-agar culture. Alternaria No. 5. | 41 | 3 | 35 | 35 | 34 | 24 | 24 | 24 |
| Total | 242 | 30 | 113 | 116 | 109 | 87 | 87 | 83 |
| Per cent | | 26 | | | 94 | | | 96 |

The explanation of the greater effectiveness of the large bits of sugar-agar cultures must lie in the greater moisture contained in the accompanying medium, since smaller pieces of the same cultures gave much fewer infections. Any possible physiological differences due to the contents of the medium would be present whether small or large amounts were used, and dextrose was also present in the potato-agar (1 per cent). Such a condition could not occur in nature, where the disease is abundant, though the percentage of successful natural inoculations cannot be de-

termined. The most plausible explanation of the difference is that of sufficient moisture for infection.

There are at least three references to species of Alternaria upon cotton and two to Macrosporium. According to Earle,[2] Gasparrini has reported *Alternaria tenuis* Nees, in association with a disease known in Italy as Palagra. The original description of this disease is not available, but when compared with the description given by Saccardo[3] many points of similarity of this species to the fungus under consideration are noticed, though the spores, according to this description (30 − 36 × 14–16) are wider than those of the species studied here. Atkinson[4] mentions an undetermined Alternaria found in connection with the rust (now known as "potash hunger") of cotton. No diagnostic characters are given and thus no comparison of the two fungi can be made.

A more recent reference to the subject occurs in a paper by Hewitt[5] in which an Alternaria was found upon the pedicels of cotton bolls which had been shed from the plant. No evidence is presented to show that this fungus is connected with the cause of the shedding or that it is able to invade healthy tissue of the plant. However the close resemblance of the spore-shape and septation (no dimensions are given) to those of this species, lead the writer to believe they are the same.

A species known as *Macrosporium gossypinum* Thum. was collected on cotton in South Carolina by Ravenel. After a careful consideration of description given by Saccardo[6] and comparison with a type specimen it seems probable that this is identical with the fungus determined by Gasparrini as *Alternaria tenuis*, and that all these fungi may be one and the same thing.

A disease of cotton leaves caused by *Macrosporium nigricantium* Atk. has been described by Atkinson.[7] There are many points of similarity in the lesions though Atkinson's disease is more common upon leaves showing evidence of potash hunger. No mention is made of any relation to the bacterial spots which Atkinson first described about this time or to red spider injury. Spores shaped as those represented in his paper have never been found upon the lesions or in cultures of the fungus causing this disease.

[2] Earle, F. S. Diseases of cotton. Alabama Agr. Exp. Sta. Bull. **107**: 289–330. 1899.

[3] Saccardo, P. A. Syl. Fung. **4**: 545, 1886.

[4] Atkinson, Geo. F. Black rust of cotton: a preliminary note. Bot. Gaz. **16**: 61–65. 1891.

[5] Hewitt, J. L. A disease involving the dropping of cotton bolls. Phytopath. **4**: 327–333. 1914.

[6] Saccardo, P. A. Syl. Fung. **4**: 525. 1886.

[7] Atkinson, Geo. F. Some diseases of cotton. Alabama Agr. Exp. Sta. Bul. **41**: 1–65. 1892.

SUMMARY

A species of Alternaria has been shown to be the cause of a leaf disease of cotton.

The lesions are characterized by a pale green, then straw-yellow and finally rusty brown color, brittle papery texture and irregular concentric ridged zonations.

The spots are usually found at the edge of or surrounding the angular spots caused by *Bacterum malvacearum*, and among red spider injuries, but may be found where no previous injury existed.

The identity of the fungus causing the disease cannot be determined with certainty, but is very similar to *Alternaria tenuis* Nees.

Artificial inoculations show the fungus to be a weak parasite and able to infect healthy tissue only under most favorable conditions.

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# DIFFERENCES BETWEEN THE SPECIES OF *TILLETIA* ON WHEAT

ALDEN A. POTTER AND G. W. COONS

## DISTINCTIONS GIVEN IN LITERATURE

Although *Tilletia laevis* (*foetens*)[1] was described as distinct from *Tilletia tritici* (Bjerk.) Wint. by Kühn (14) in 1873, these two species of stinking smut seem never to have been adequately separated and are more or less confused in pathological literature and collections. Indeed, Kühn's original material was mixed with *Tilletia tritici*, according to Clinton (8, p. 432). The writers have also found the following errors in exsiccati represented in the collections of the Bureau of Plant Industry of the United States Department of Agriculture:

Briosi e Cavara. I Funghi parassiti delle piante coltivate od utile. Nr. 155, *Tilletia tritici*. The accompanying illustration is correct, but the specimen is *T. laevis*.

Raciborski, M. Mycotheca Polonica. Nr. 12, *Tilletia caries* (DC.) Tul. The specimen contains both *T. laevis* and *T. tritici*.

Saccardo, P. A. Mycotheca Veneta. Nr. 373. *Tilletia laevis* Kühn. apparently undiseased.

Sydow, Paul. Ustilagineen. Fasc. XI (1911), Nr. 440, *Tilletia tritici* (Bjerk.) Wint. In ovariis *Tritici compacti* Hort. Collected by Fr. Bubák in Bohemia. Specimen is of *T. laevis* Kühn. The writers detected this error because the specimen did not conform to the description and illustration of club wheat affected by *T. tritici* given by Heald and Woolman (12, p. 8–9). Bubák's specimen has the normal form of head for *Triticum compactum*.

Kühn distinguished the two species only on the basis of spore characters and he states that in other characteristics they are essentially alike. The same idea is expressed by Appel (1, p. 2) who states that there is no practical significance in the distinction. In recent papers by Appel[2] (2) and

[1] McAlpine (15, p. 192) rejects *Tilletia foetens* (B. & C.) Schröt. (Trel.:), because *Ustilago foetens* Berkeley and Curtis (4) was not accompanied by a description. Schröter (17, p. 365) had transferred *U. foetens* to *Tilletia* seven years before Trelease (21) transferred it.

[2] This author's interpretation of the change in the shape of the head as atavistic seems dubious, particularly in view of the apparent lack of identification of the species of the parasite.

other writers (3, 9, 16, 19) concerning the morphology of the diseased host, the possibility of differences between the two species of the parasite is evidently overlooked. This attitude as to the importance or possibility of distinguishing these species in the field has appeared repeatedly in American literature, notably in bulletins by Kellerman and Swingle (13, p. 49), by Bolley (5, p. 110) by Swingle[3] (20, p. 6), by Clinton (7, p. 319, footnote), and by Heald (11, p. 1); and in his monograph of the smuts of Australia, McAlpine (15, pl. 2) has used a single photograph to illustrate both species.

It would appear that the only observations making possible a distinction between these two species in the field were made by Mr. Enos Holmes, a farmer of southwestern Michigan, who noted that the stinking smut of wheat occurred in two types, "high" and "low." These observations were verified and published, without illustration, in a bulletin by Harwood (10, p. 5–6) in 1892. This important note on the difference in the development of the host as to height, has for some reason been very largely ignored in the literature of the subject, possibly in part because Selby (18, p. 35–36) has stated that he was unable to verify the statements of the Michigan bulletin. It seems possible, however, that he lacked material for comparison since he remarked that *T. laevis* (*"foetens"*) was the only species about Wooster (Ohio); at any rate he confused the statement of the Michigan writer as to the relative height of the two species. Nevertheless McAlpine (15, p. 55) also states his inability to confirm Harwood's note, although his observations do not appear to have been sufficiently extensive to warrant very definite conclusions. While there thus remains some doubt as to the general applicability of this distinction in height, the writers have been able to fully confirm the accuracy of the observations given by Harwood and believe that the distinctions between the species may have a wider applicability than has been recognized.

## OBSERVATIONS IN MICHIGAN

During a visit to fields in Kent County, Michigan, in July, 1917, it was observed that the smutted wheat (fig. 1) clearly fell into two distinct classes, the "high" smut, slightly shorter (2 to 4 inches) than normal culms, and the "low," averaging fully a foot shorter than the height of healthy plants. The taller form, on microscopic examination, was found to be *Tilletia laevis* Kühn, and the shorter one, *Tilletia tritici* (Bjerk.) Wint. The stunting effect of the latter appears to be a specific reaction of the host, and plants showing complete and exclusive infection by this species were practically uniform in height. In the aberrant cases where the plants

[3] Swingle cites Harwood's observations in a footnote.

affected by *T. tritici* were noticeably taller than the average for the species, the heads were found to be only partially invaded. A few heads were found with sori containing spores of both species. The height of such plants was intermediate between the normals for the species.

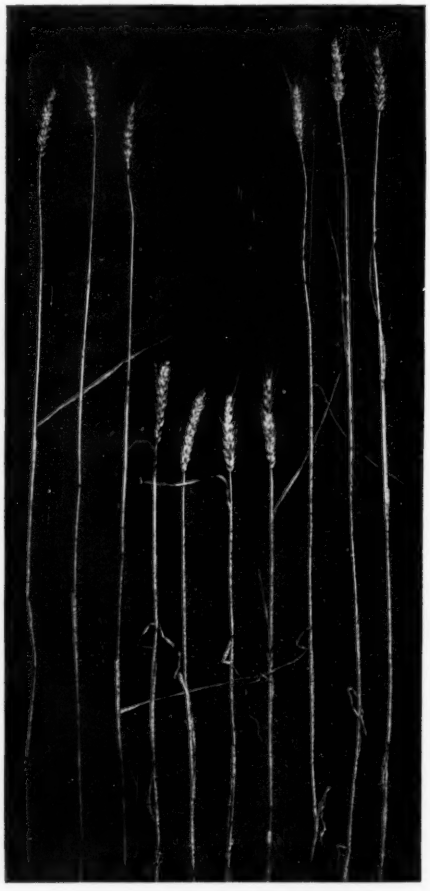

FIG. 1. RED ROCK WINTER WHEAT FROM KENT COUNTY, MICHIGAN

Showing typical stalks affected with *Tilletia laevis* Kühn (left) and *Tilletia tritici* (Bjerk.) Wint. (center), with normal stalks on the right for comparison. Note that the first are almost normal in height while *T. tritici* has materially dwarfed the host.

Other differences between the two species of bunt were also noted. The heads infected by *T. tritici*, instead of being rendered smaller and more slender and open in structure than normal, as is the case with *T. laevis* infections (at least while immature), were enlarged (fig. 2). Usually all the apical florets in the spikelet bore sori (smut balls or false kernels), these being produced where kernels would not normally have developed (figs. 2 and 3). This condition was not found in the case of infections with *T. laevis*. Accordingly the spikelets in heads infected by *T. tritici* were more crowded and had a more nearly bilaterally symmetrical appearance. The sori, too, differed in shape, as will be seen in figures 3 and 4. This difference would suggest that McAlpine's material, illustrated in his plate II (15), was *T. tritici*.

The writers have found strong indications that *T. tritici* is related in some way to soil conditions much more than is *T. laevis*, as the species occur in Michigan. Very similar observations were recorded in Holmes' letter, quoted by Harwood (10, p. 5), and if they may be taken as evidence of soil infestation by *T. tritici*, McAlpine's choice of this species in preparing his illustration seems significant,

for in Australia, as on our own Pacific Coast where *T. tritici* prevails, copper sulphate is preferred as a seed treatment on account of its residual effect in preventing reinfection, presumably from the soil for the most part (see Heald and Woolman, 12, p. 17). Indeed, it appears probable to the writers that the serious problem of soil infestation in the Palouse district of eastern Washington and neighboring parts of Idaho (l.c., p. 11–13) is largely a question of the species of the parasite. For the same reason Bolley (5, p. 121 et seq.), who had only *T. laevis* to deal with, did not find the matter of soil infestation in the fields of Dakota to be of any importance. In the Palouse area the dwarfing of the host by *T. tritici* has undoubtedly added considerably to the difficulties of the situation because the very general use of header and combined harvesters has made it possible to skim the good heads off the field, leaving the smutted ones to contaminate the soil more heavily. Even with selfbinders this soil infestation takes place to some extent wherever *T. tritici* occurs, for though cut, the short, smutted heads are not tied in well and hence fall out of the bundles. Such dropping from the bundles was noted by Holmes in his letter to Harwood (10, p. 6). These heads, left on the field after harvest, constitute a source of infection which, if not as serious as the so-called smut showers, are much more persistent and difficult to eradicate (see Heald and Woolman, 12, p. 11).

FIG. 2. HEADS OF RED ROCK WINTER WHEAT ($\times \frac{1}{2}$)

Showing effect of *Tilletia laevis* (left) and *Tilletia tritici* (right), with a normal head for comparison. Of the affected heads the former is smaller and the latter larger than normal, and in the latter the stem is also thickened. The specimens, collected just before ripening, were in a soaked condition when photographed.

With the material from Michigan, the observation of the writers is that

the consistency of the smut mass in *T. laevis* is inclined to be somewhat unctuous, while in *T. tritici* it has a more powdery or even granular friability, as indicated in figure 4. Such a difference would seem to be the natural outcome of the well-known difference in the character of the epispore. It is also in accord with the observations of Holmes given in the Michigan bulletin cited (10) as to the different way in which the two species behave during thrashing. That this powdery condition in *T. tritici* is of even greater consequence than is suggested by Holmes' remarks,

FIG. 3. SPIKELETS AND KERNELS OF RED ROCK WINTER WHEAT (Nat. size)

Soaked specimens, showing *Tilletia laevis* (left) and *Tilletia tritici* (right), with a normal spikelet and kernels for comparison. Differences in the shape of the sori, in the appearance of the spikelets due to number of sori produced and their shape, and in the awns, are to be noted.

seems highly probable, for in the Palouse district where *T. tritici* is known to be very prevalent, explosions in thrashing machines have been a source of serious losses (see Cardiff, 6).

Many facts connected with the condition of the smut in the thrashed grain also lend themselves readily to explanation on the basis of this difference in friability. The interpretation of these effects, however, is complicated by climatic factors, as has been pointed out by McAlpine, (15 p. 193). In this country the condition of the smut in the thrashed grain is also affected by the fact that in the far west where conditions are gen-

erally dry and we have at the same time to deal almost exclusively, with *T. tritici*, the grain has been very generally handled in bags, while in the east where climatic conditions are more humid and *T. laevis* is the dominant form, the practice of handling the grain in bulk tends to break up the smut sori and so produce a more dirty appearance in the grain. It is nevertheless a noteworthy fact that so different a system of grading and dockage for smutty wheat has developed on the Pacific Coast that it has been necessary to recognize it in establishing regulations under the recent Grain Standards Act.[4] The method used on the Pacific Coast appears to be based largely on the fact that, by the "scouring" process used, the smut

FIG. 4. NORMAL KERNEL OF RED ROCK WINTER WHEAT (CENTER) WITH DRIED SORI OF *Tilletia laevis* (LEFT) AND *Tilletia tritici* (RIGHT) (× 3)

Showing difference in shape and indicating also a difference in the consistency of the spore mass.

is more easily separated from the grain than has been found to be the case in the east.

## DISTRIBUTION OF THE SPECIES

It is commonly accepted as a fact that the Upper Mississippi Valley and Great Plains states, and for the most part other eastern states as well, are comparatively free from *T. tritici*, although the species has been reported as widely distributed (see Clinton, 8, p. 433). It may be that conditions do not favor the development of this species in the east; or it may be that

[4] Official Grain Standards of the United States for Wheat. U. S. Dept. Agr., Off. Markets and Rural Organ., Serv. and Reg. Announcements, 22, p. 28–29. 1917. The first method given is that used on the Pacific Coast.

the reported scarcity of the species is due to varietal characters, particularly resistance, in the hard wheats (of both spring and winter varieties) so largely grown in the states where the bulk of the wheat crop is produced. If the latter be true it would add emphasis to the importance of a general study of the resistance of varieties of wheat to bunt, particularly to *T. tritici* on account of the apparent greater difficulty in eradicating this species. Varietal resistance already appears to have been a factor of no little importance in the history of wheat-growing in Michigan. At one time, according to Mr. E. H. Rogers of Kent County, a variety which had been successfully cultivated in that district was driven out of use because smut infection became so prevalent that losses as great as 50 per cent or more were not uncommon. This condition would parallel that now prevailing in the Palouse country if we may but suppose that it had been induced by *T. tritici*. Certainly, varieties should not be recommended for districts where *T. tritici* is known to occur until they have been carefully tested for resistance to this species.

It is hoped that this note may stimulate observations along the lines indicated in other sections of the country, so that the general importance of the distinction which is so evident in Michigan, may be confirmed or its limitations more exactly defined. If the two species can be as readily differentiated in the field as would appear from these observations, it would seem desirable to determine more accurately their present distribution. Such a survey might furnish a basis for highly desirable quarantine measures to prevent introduction of either of the species where it is not now prevalent.

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# NOTES ON FOREST TREE RUSTS

JAMES R. WEIR AND ERNEST E. HUBERT

## PERIDERMIUM COLORADENSE

Abundant collections of both the pycnial and aecial stages of *Peridermium coloradense* (Dietel) A. & K. were made in 1917, on *Picea engelmanni*. The conspicuous pale yellow color of the infected needles composing the witches'-brooms caused by this fungus is a very ready means of locating such brooms in the early part of the season. At this stage the pycnia are developing and a very pronounced odor accompanies them.

An attempt has been made to determine, if possible, the alternate stage of this rust. Since the rust, in its microscopic characters and in its habit of forming witches'-brooms closely resembles *Melampsorella elatina* (A. & S.) Arth., it was believed that some species of Stellaria or Cerastium carried the uredinial and telial stages. A search was made to locate possible hosts in the vicinity of spruces bearing many brooms. *Stellaria borealis* and *S. longifolium* were both found growing along the edge of a stream near Evaro, Montana, and just beneath a group of infected spruces. The rust on the spruces being in the pycnial stage of development, no infections were expected and none found on the Stellaria plants. Later when the aecial stage matured, inoculations were made in the greenhouse at Missoula, Montana, under controlled conditions as follows: Aeciospores of *P. coloradense* were sown on *Pyrola elliptica* on May 15, 1917, on *Cerastium arvense* on May 25, on *Stellaria longifolium* and *S. borealis* on June 26, and *S. borealis* on July 23. On July 6, uredinial pustules appeared on the lower leaves of *Stellaria longifolium* and *S. borealis* (No. 83*).[1] On August 4, uredinia appeared on *S. borealis* (No. 85*) inoculated on July 23. A few teliospores were noted September 4. Control plants remained normal and the other trial hosts were free from infection. Examination of the urediniospores secured from the above cultures showed a similarity in size, shape, and markings to the descriptions given for *Melampsorella elatina*, also in comparison with authentic material of the uredinial stage of the rust on Cerastium (Fungi Columbiana No. 2232; Jackson Collection No. 2667; collection sent by Bethel, No. 114*). On July 25, aeciospores of *M. elatina* on *Abies grandis* were

[1] All numbers cited in this article marked with an asterisk refer to collections at Missoula, Montana.

sown on two clumps of *Stellaria borealis*. On August 10, uredinia appeared in abundance on plants in both pots. Telia were found on August 30 (No. 69*). On July 26, aeciospores of *M. elatina* on *Abies lasiocarpa* were sown on several plants of *Stellaria borealis* contained in one pot. On August 10, a heavy uredinial infection was noted. Telia were found on September 1 (No. 70*). Control plants remained normal. Examinations of the uredinial and telial stages resulting from inoculations with aeciospores taken from *Picea engelmanni*, *Abies grandis*, and *Abies lasiocarpa* indicate that they belong to one and the same fungus, *M. elatina*. Bethel in a letter on September 30, 1917, remarks, "*Peridermium boreale* Kern on *Picea pungens* is common in Colorado and is doubtless identical with *Peridermium coloradense* A. & K. *Melampsorella elatina* (A. & S.) Arth. on *Cerastium occidentale* is usually associated with it and in some isolated localities has been found to be the only rust nearby which could possibly be connected with the Peridermium." In August, 1917, Dr. C. H. Shattuck, at that time a member of this office, sent to the Laboratory a large witches'-broom on *Picea excelsea* collected at the Mix Nursery of Moscow, Idaho. Upon examination, the rust (No. 1225*) causing the broom was found to be *Melampsorella elatina*. This is the first record of this fungus attacking *Picea excelsea*. A collection of *M. elatina* on *Picea parryana* (No. 8226*) was made at Superior, Wyoming, on August 10, 1917, by Mr. Simmons of this Office. The season's (1917) field observations show this broom-forming rust of spruce to be very wide-spread and in some localities very harmful. It has been found attacking and stunting the tips and branches of young trees, as well as causing brooms and a dwarfing of saplings and older trees.

### CALYPTOSPORA COLUMNARIS

*Calyptospora columnaris* (A. & S.) Kuehn occurring upon species of Vaccinium has its aecial stage upon species of Abies in the form known as *Peridermium columnare* (A. & S.) Kunze & Schmidt. Cultures of this fungus were made on *Abies fraseri* by Arthur[2] in 1910. Collections and cultures were made by Fraser[3] on *Abies balsamea* in 1911, 1912, and 1914.

Abundant collections of the telial stage of *Calyptospora columnaris* on species of Vaccinium have been made throughout the forests of the Northwest and always in localities where *Peridermium columnare* and *P. ornamentale* occurred on species of Abies. A comparison of the aecial stages

[2] Arthur, J. C. Cultures of Uredineæ in 1909. Mycologia **2**: 231. 1910.
[3] Fraser, W. P. Cultures of some heteroecious rusts. Mycologia **3**: 71. 1911.
——— Cultures of heteroecious rusts. Mycologia **4**: 177. 1912.
——— Notes on Uredinopsis mirabilis and other rusts. Mycologia **6**: 27. 1914.

of *P. columnare* (N. A. U. No. 1203; Jackson collection No. 3294; collections sent by Fraser, No. 73*; and a collection determined by Arthur, No. 74*) with *P. ornamentale* (part of the type *P. holwayi*) and Nos. 75* and 145* determined by Arthur) shows a striking similarity in such characters as overlapping of peridial cells, size, shape, color and marking of spores, and presence of intercalary cells. The principal difference between the two appears to be in the shape of the peridia, those of *P. columnare* having usually cylindrical and those of *P. ornamentale* slightly flattened peridia. Anastomosing of cylindrical peridia often result in a flattened appearing column, and this character, it seems, is not sufficient to separate the two species. It is very readily observed that the size and vigor of the needles very largely determine the character of the peridia. Needles growing in the open and of large size have flattened peridia. On the same branch the needles suppressed by shade or by vegetation growing up around them have cylindrical peridia. A further difference as given in the descriptions is the rarity or entire absence of pycnia for *P. columnare*. A collection of typical *P. columnare* in the aecial stage on *Abies grandis* was made near Columbia Falls, Montana, on July 20, 1917 (No. 1227*). In this collection five or six needles were found showing evidences of pycnia. Upon examination oval, hyalin pycnospores were found. The pycnia in one case appeared as brownish to blackish dots on either side of the midrib of the leaf and occupied that portion of the needle next to the twig, while the other portion bore immature aecia.

A difference in the physiological and morphological characters of the needles of the hosts as stated above seems responsible for the variations noted. It has been recently demonstrated by Long[4] that the host materially alters the morphological characters of species of Puccinia. There seems to be no good reason why host influences should not affect the morphological characteristics of other rusts as well.

Collections of *P. ornamentale* on *Abies lasiocarpa* made near Victor, Montana, on August 4, 1917 (No. 80*), in absolute contact with Vaccinium bearing the Calyptospora rust indicate the relationship of the two forms. No other needle rust on Abies was found in this locality and the two forms *P. ornamentale* on *Abies lasiocarpa* and *Calyptospora columnaris* on Vaccinium were very abundant. Other collections have been made in 1916 under similar conditions to the above. Cultures are necessary in order to determine the relationship definitely but field observations and comparisons of microscopic and macroscopic characters point to the identity of the two forms *P. ornamentale and P. columnare.*

In a communication dated March 14, 1916, regarding *P. ornamentale*

[4] Long, W. H. Influence of the host on the morphological characters of Puccinia ellisiana and Puccinia andropogonis. Jour. Agr. Research **2**: 303. Jy. 1914.

and transmitting type material of *P. holwayi*, Doctor Arthur states that he is satisfied that the latter is identical with *P. ornamentale*. He further states that "the host of *P. holwayi* is not *Abies douglasii* (*Pseudotsuga mucronata*) but *Abies lasiocarpa*."

Summing up the data presented it appears that *Peridermium holwayi*, *P. ornamentale* and *P. columnare* are to be considered identical, and *Calyptospora columnaris* indicates the fungus in whatever stage it may be found.

### MELAMPSORA ARCTICA

The aecial stage of *Melampsora arctica* Rostr. was collected in the Coeur d'Alene regions of Idaho on several dates in July and August, 1916, upon *Abies grandis* and *A. lasiocarpa*. This rust was frequently found associated with the aecial stage of *Pucciniastrum pustulatum* (Pers.) Dietel, on the same hosts and often on the same needles (N. A. U. No. 1680). When sporulating the bright orange color of the spore-mass is quite characteristic and along with its caeoma-like habit distinguishes this fungus from the rust accompanying it. A peculiarity of the aeciospores noted in about half of the spores examined, when comparing with authentic material for identification, was the evident thickening of the cell wall at one end of the spore. This character was found constant in examining Fraser's collections on *Abies balsamea* and *A. canadensis* (Nos. 76* and 77*), in a collection on *Abies concolor* (No. 88*) contributed by Bethel, and in collections from Montana and Idaho on *Abies grandis* and *A. lasiocarpa* (Nos. 78*, 79*, 89*, 90*, 91*, 92*, 93* and 94*).

Fraser in 1912[5] and in 1913[6] recorded the successful cultures on *Abies balsamea*. The resulting aecial stage on Abies was found to be a Caeoma identical with a Caeoma previously found on the native Abies. A brief description of the aecial stage was given.[5] Ludwig[7] adds further information on this interesting rust by stating that the pycnia are subcuticular but instead of being situated on top of the epidermal cells, as is usual with subcuticular pycnia, they are situated in a cavity in the epidermis caused by the disintegration of the epidermal cells.

Bethel, who very kindly gives permission to refer to his studies, states in a letter of April 19, 1917, that he has successfully cultured the caeoma stage of a rust on *Abies* sp. by sowing teliospores of a species of Melampsora developing on Salix. This Melampsora he regards as being distinct from *M. arctica*. From these data it is difficult to say whether Bethel's

[5] Fraser, W. P. Cultures of heteroecious rusts. Mycologia **4**: 187. Jy. 1912.

[6] Fraser, W. P. Further cultures of heteroecious rusts. Mycologia **5**: 238. Jy. 1913.

[7] Ludwig, C. A. Notes on North American rusts. Phytopath. **5**: 280. 1915.

results are secured from a new species or from *M. arctica*, although the collection of the aecial stage on *Abies concolor* sent by him, when examined, coincided in its gross and microscopical characters with Idaho and Montana collections of *M. arctica* on *Abies* spp. and with the given descriptions.

Aeciospores of *M. arctica* on *Abies grandis* collected at Evaro, Montana, July 8, 1917 (No. 1232*), were sown on two plants of *Salix scouleriana* on July 9, 1917. On August 2, 1917, the first evidence of infection was noted in the yellow areas on a few leaves. On August 4, uredinia appeared (No. 84*). These were characterized by their very small size. This completes the cycle and checks the culture by Fraser[5] made in 1912, who succeeded in infecting *Abies balsamea* with the telial stage of *Melampsora arctica* collected on *Salix discolor*.

SUMMARY

*Melampsorella elatina*. Aeciospores of *Peridermium coloradense* on *Picea engelmanni* sown on *Stellaria longifolium* and *S. borealis*.

Aeciospores of *Melampsorella elatina* on *Abies grandis* sown on *Stellaria borealis*.

Aeciospores of *M. elatina* on *Abies lasiocarpa* sown on *Stellaria borealis*.

A comparison study of the spore forms resulting from the above inoculations indicates they are the same rust, namely, *Melampsorella elatina*.

A new host for *M. elatina* reported, viz., *Picea excelsea*.

The rust causes a harmful witches'-broom and a dwarfing of tips and branches.

*Calyptospora columnaris*. A study of the forest tree rusts known as *Peridermium holwayi*, *P. ornamentale*, and *P. columnare* on species of Abies indicates that they are identical, and the name *Calyptospora columnaris* represents them all.

*Melampsora arctica*. Aeciospores of *M. arctica* on *Abies grandis* sown on *Salix scouleriana*. This culture identifies a rust of this region which is commonly found associated with *Pucciniastrum pustulatum* on living needles of *Abies grandis* and *A. lasiocarpa*. An apparently new spore character is noted for aeciospores of *M. arctica*.

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# FIELD STUDIES OF CERCOSPORA BETICOLA

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With Two Figures in the Text

Some of the conditions which influence the development of *Cercospora beticola* Saccardo on the sugar beet have been studied by the writers in the Arkansas Valley of Colorado and near Madison, Wisconsin, from 1912 to 1914 inclusive. The results of the studies presented here include artificial infection, sources of field infection and the influence of different field and feeding practices on the development of the disease.

## ARTIFICIAL INFECTION

Several attempts were made in Colorado in 1912 and 1913 to secure artificial infection of sugar beet plants in the field and in the greenhouse but poor results were obtained. Consequently, a more detailed study of some of the factors controlling infection were undertaken. Among other things it was determined that a temperature of 80° to 90° F. by day and a minimum of not less than 60° F. by night with a relative humidity above 60 for not less than fifteen to eighteen hours per day offered the most favorable opportunity for infection.[1] Approximating these conditions a high percentage of infections was secured at Madison during the summer of 1914 by keeping plants in the field covered with cheesecloth for a few days previous to and following inoculation. In one set of inoculations in which newly produced conidia fresh from the field were used as inoculum, from 800 to 12,000 spots appeared on the inoculated plants in eleven to thirteen days while the check plants remained entirely free from infection. When the humidity remained high during the day, morning inoculations seemed to give nearly as good infection (550 average per inoculated leaf) as evening inoculations (800), however, evening inoculations were somewhat more dependable. Lower leaf inoculations gave apparently as good infection (602) as those made on the upper leaf surface (611).

Efforts were made to infect sugar beet plants by using artificial cultures of the fungus as inoculum but only slight infection was secured and in no case was such material nearly as satisfactory as fresh conidia from lesions on sugar beet leaves.

[1] Pool, Venus W. and McKay, M. B. Climatic conditions as related to infection by Cercospora beticola. Jour. Agr. Res. **6**: 21–60. 1916.

During the course of the studies of this sugar beet disease, leaf spots caused by *Cercospora* spp. have been encountered either in person or indirectly on several other hosts, and inoculations were made at Madison in 1914 with *Cercospora beticola* on a number of plants to determine some of its host limitations. Mangel-wurzel, Swiss chard and red garden beet were apparently almost as susceptible to infection as the sugar beet. No infections were obtained on *Amaranthus retroflexus*, *Chenopodium album*, *C. quinoa*, or *Lactuca sativa*, while numerous spots (217 on 20 inoculated leaves) developed in fifteen days on the only new host encountered, *Martynia louisiana* Mill. These latter spots were circular, from 4 to 7 mm. in diameter, brownish, turning gray in the center with age due to the production of conidia, and were typical of the spots on this plant as found in nature in and near sugar beet fields in Colorado where it exists as a more or less common weed.

## SOURCES FOR INFECTION OF FIRST AND SECOND YEAR BEETS

The greatest source for the primary infection of first year beets proved to be the old and partly buried beet tops left on the ground from the preceding crop. Infected beet balls were another source but under the conditions which surrounded the present work they were of less importance although a serious development of the disease might result from such infection. The development of the disease in first year beets used as "stecklings" is of direct importance to its occurrence in second year or "mother beets."

### *Old beet top material*

*Cercospora beticola* may remain alive throughout the winter months in the infected beet tops left scattered over the field after harvest and thus be in a condition to serve as a source for infection of the growing beet plants the following season. It has already been shown[1] that if the beet top material is left in the field and becomes slightly covered with soil, as frequently happens during harvest and afterwards when stock is pastured on the land, the organism receives sufficient protection to survive the winter temperatures, but if the beet tops are plowed under in the field to a depth of from 6 to 8 inches they become so entirely disintegrated that the viability of the organism becomes destroyed.

To determine to what extent diseased beet tops from the previous crop were a source for infection, diseased leaves which had been kept through the winter in the interior of a "hayed" pile of beet tops and which had yielded good growth of *Cercospora beticola* in recent cultures, were in the spring of 1913 placed around vigorously growing plants in one plot in the experimental field. At the time the experiment was started no

spots had been found in this entire field. After a lapse of four weeks new conidia were found produced in abundance from the spots on the old overwintered leaves, and the growing leaves which were in close proximity showed a heavy infection, some having as many as 40 spots. Outside of this one plot, no spots were found on any other plants in the experimental grounds, thus indicating that the old tops were the source of the infecting fungus.

A study of infection as it occurred naturally in the fields in 1912 showed that in all those fields which had been in beets for two or more successive years and in which the beet top material of the preceding season was usually left scattered over the ground after harvest, serving as the source for infection, the oldest leaves or those nearest the ground were the first to become infected. On July 12, 1912, on 18 plants, o average infection, studied in detail in three such non-rotated fields, the lowest leaves on the plant had the greatest average number of leaf spots (Leaves 1 to 7, numbered in the order of their appearance, had 5.2, 5.4, 3.7, 1.7, 2.3, 3.1, and 1.1 spots per leaf respectively) while the number of leaf spots quickly decreased as the distance of the leaves from the ground increased (Leaves 8 to 17 had 0.5, 0.1, 0.5, 0, 0.5, 0, 0, 0, 0, 0, spots respectively), the third whorl of leaves (beginning with leaf 8) showing a distinct decrease.

In great contrast to the early occurrence of such primary infections in non-rotated fields the first infections in rotated fields, which had no source for infection from the soil, occurred two weeks later and appeared on those leaves which were farther away from the ground surface (July 29, Leaves 1 to 17 had 0, 0, 0, 0.1, 0.8, 0.1, 1.3, 0.8, 1, 1, 1.4, 1.4, 0.9, 0.9, 0.6, 0.3, 0.4 spots per leaf respectively). No infections were ever observed to occur on the oldest leaves of these plants.

*Effect of top-removal on the disease.* A seasonal study of the disease was made in several fields to determine the effect of careful top-removal after harvest on the occurrence of the disease in non-rotated fields the following year. In one case plants in a 5-acre field which had been in sugar beets for two successive years were rather heavily attacked by *C. beticola* in the late summer of 1912. The disease was fairly abundant and generally distributed throughout the field, a large number of the functional leaves being infected with an average of approximately 300 spots per leaf. Several of the leaves on each plant were dead, many of which were infected, indicating that the disease had been present in the field the greater part of the summer. At harvest time the beets from fourteen adjoining rows were thrown together in one row across the field and were then topped, the tops being allowed to lie where they fell. The tops were removed from the field when well cured, leaving the ground quite clean. The latter part of the following April, that is in 1913, the ground was planted

to beets, and by the last of June the plants were in good condition and had well-developed foliage. Examinations of the field for the presence of leaf spot were made June 26, July 3, 9, 17, 21, 29 and August 4, but no disease was found. On August 10, however, a few spots were observed near the place where the field was usually entered suggesting that the fungus may have been carried into the field on the clothes o the workers. During August the disease in this area increased slightly, and by the middle of September approximately three-fourths of the plants were lightly infected. On September 19, detailed observations were made in this field and for purposes of comparison in a nearby non-rotated beet field from which the beet tops had not been removed after the preceding harvest. The amount of disease on a few representative plants in each field was tabulated and a remarkable difference was found to exist between the two fields. In the field from which the leaves had been removed there was an average of only 17 spots per infected leaf as compared with 490 in the other field and none of the leaves was killed by the disease as against 17.5 leaves per plant. In the former field the plants produced on the average a fewer number of leaves during the season, 43 as compared with 55, though as a result of the lighter attack of disease in this field it possessed even more functional leaves per plant than the other field, 36.2 as compared with 20, thereby making possible greater sugar production.

These results not only indicate that the disease may be largely controlled by proper removal of the beet tops after harvest, but also strengthen the view that, in the localities where studies were made the principal source for the primary infections in non-rotated commercial fields is in the old diseased beet top material from the preceding crop left on the ground after harvest.

### *Beet balls*

*Foreign-grown seed.* Twenty-eight strains or varieties of foreign-grown seed commercially imported into this country were examined to determine whether they were infected by *C. beticola* and whether viable conidia were present. These tests included samples from the commercial outputs of the years 1907, 1908, 1910, 1911, 1912, and 1913. Approximately thirty balls of each variety were washed through 10 cc. of sterilized water and the next day a portion of the suspension or the centrifuged sediment was examined, but only rarely were conidia found and none of these were viable. Other cultural tests were made by washing 50 beet balls of each of the varieties in 10 cc. of sterilized water after which 0.1 cc. of the water was used for each of 250 plate cultures. The same balls were then treated with mercuric chloride, 1 to 1000, for one-half minute, rinsed through three washings of water, macerated, and por-

tions placed in tubes for 354 poured plates.[2] No growth of *C. beticola* was obtained in any of the cultures in either series.

A search in the field for infections from beet seed was made over approximately 200 acres of rotated fields planted with the seed from which the samples were taken for the above cultural tests. Infections in these fields were found to occur only after the disease had appeared in non-rotated fields. If the beet balls had been infected numerous cotyledonous infections would probably have occurred, as will be shown later. The absence of any infection on the cotyledons and on the older, lower leaves together with the results of the other experiments seemed conclusive evidence that the beet balls, even if originally infected did not carry the fungus in a viable condition.

*Home-grown seed.* The sugar beet seed produced in the breeding plots at Madison in 1913 were found to be heavily infected with *C. beticola*. Many of the calyx tips were blackened and covered with numerous conidiophore tufts of the fungus and there were also well defined leaf spots on many of the subtending bracts which remained attached to the beet balls when harvested. The mother beet stalks, leaves and petioles were so heavily attacked by the fungus (fig. 1) that many of the plants produced no seed worth harvesting and the total yield from the field was greatly reduced. Tests were made in January, 1914, on the beet balls from these plots to determine the presence and the viability of the conidia of the fungus. One test with 30 balls gave 116 conidia, 3 of which germinated, and another test with the same number of balls gave 75 conidia, 4 of which germinated. Seventeen colonies of *C. beticola* were produced in one petri dish culture from macerated portions of 2 beet balls and 23 colonies in another culture from three infected calyx tips.

Various treatments of beet seed for the control of *C. beticola* have been advocated by Frank[3] and Linhart[4], such as soaking in Bordeaux mixture, pasteurization, "shelling," and immersion in concentrated sulphuric acid, but Knauer[5] and Kühle[6] were doubtful as to the effective-

[2] After the beet balls were treated with mercuric chloride and washed, tests were made to determine whether the water used in the third washing contained sufficient mercuric chloride to inhibit growth, 2 cc. of the third wash water being placed in fresh yeast cultures for the purpose, but no hindrance to growth was observed.

[3] Frank, A. B. Neuere Beobachtungen über die Blattfleckenkrankheit der Rüben (*Cercospora beticola*). Zeitsch. Ver. Rübenzuckerindus. Deut. Reichs. **47:** (n. F. Jahrg. 34) Tech. T.: 589–597, *pl. 8.* 1897.

[4] Linhart. Bekämpfung der infectiösen Krankheiten des Rübensamens. Osterr. Ungar. Zeitsch. Zuckerindus. u. Landw. **28:** 443–445. 1899.

[5] Knauer, Ferdinand. Der Rübenbau. Neubearb. von M. Hollrung. Augl. 9: 102. illus. Berlin. 1906.

[6] Kühle, L. Die wichtigsten Rübenkrankheiten und deren Bekämpfungsmassnahem. Deut. Zuckerindus., Jahrg. **31:** No. 41, col. 1601–1604. 1906.

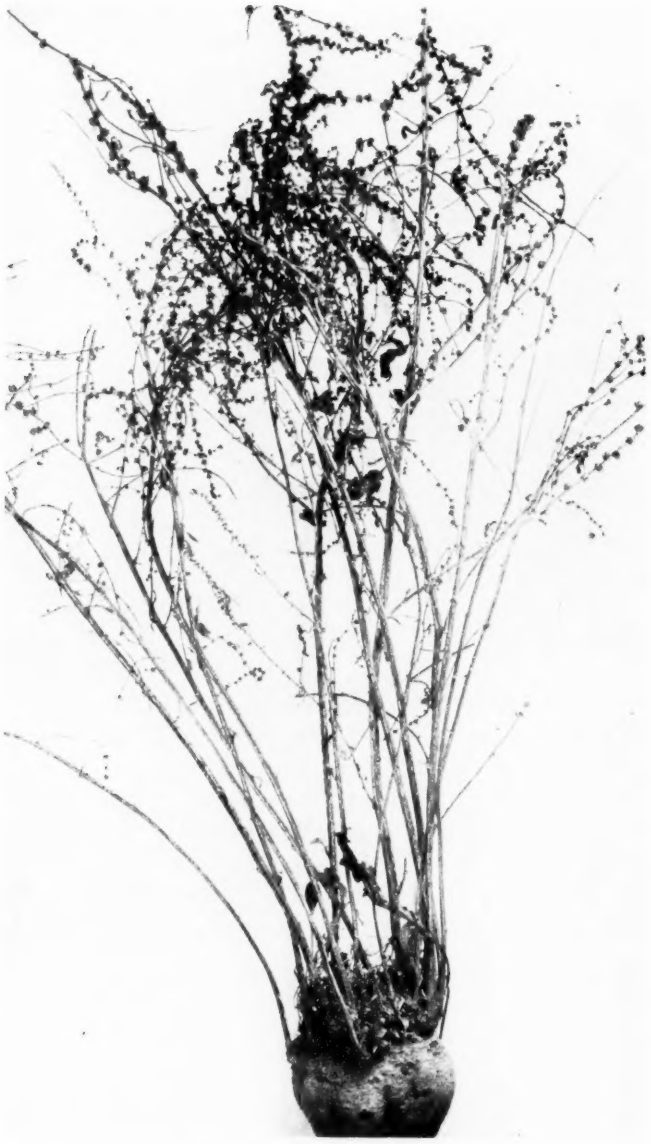

FIG. 1. LESIONS OF CERCOSPORA BETICOLA ON SEED STALK OF SUGAR BEET. The plant has been entirely defoliated by leaf spot. (Photo by L. W. Brown, University of Wisconsin.)

ness of any such treatment. Tests of several of the better-known methods of seed treatment were made by the writers on home-grown seed heavily infected with *C. beticola*. Some of the treatments were tested out on infected leaf tissue as the effect on the fungus could be determined better in this way than if beet balls had been used. The cultures made to determine the effectiveness of such treatment indicated that treatment with formaldehyde from 2 to 1000 up to 10 to 1000[7] for five minutes, mercuric chloride 1 to 1000 for five and ten minutes, and Bordeaux mixture, 5–5–50, for one and one-half hours when applied to infected leaf material reduced the amount of growth of the organism but did not kill it entirely; and that treatment of both leaf and beet ball material by pasteurization at 60°C. for ten minutes on each of two successive days and soaking with formaldehyde from 15 to 1000 up to 40 to 1000 for five minutes resulted in killing all portions of *C. beticola* present in the infected tissues. Check cultures made at the same time showed that the fungus was very abundant and viable in the untreated material.

To determine the effect of these treatments on the germination of the beet seed, standard germination tests were made. The untreated beet balls produced only slightly more than one-half as many sprouts (36,600 per kilogram) as are required in the average norm for beet ball germination (70,000) which undoubtedly was due to the extreme leaf spot infection during an early period in the growth of the seed plants. However, it appears from comparisons of the checks with the treated lots, that germination was inhibited or injured only after the death-point of the fungus was well passed. (Seed treated with formaldehyde 15 to 1000 and 40 to 1000 for five minutes gave 38,600 and 34,200 sprouts per kilogram respectively.)

Tests for the control of the disease by seed treatments were made both in the greenhouse and in the field. During the spring of 1914, several hundred plants were grown in the greenhouse from seed both untreated and treated for seven minutes in a solution of formaldehyde 15 to 1000. The plants from the untreated seed showed infections on the cotyledons (fig. 2) seventeen days after planting, while those from the treated seed remained free from leaf spots several weeks longer or until they became diseased from secondary infections. Treated and untreated seed were also planted near Madison in five widely separated plots which had not been in beets for many years. No cotyledonous infections developed on the plants grown from treated seed while on those grown from untreated seed cotyledonous infections appeared as early as June 15. The first spots in the treated plots were found on July 17 and these were limited to only one

[7] Ten parts of formaldehyde (commercial 40% tested) to one thousand parts of water.

plant grown from seed treated with Bordeaux mixture 5–5–50. Even by July 28 a little less than 10 per cent of the plants from the treated seed were affected by the disease with an average of about 3 spots per infected plant. On the other hand on the same date in the three plots

FIG. 2. SUGAR BEET PLANT FROM A BEET BALL INFECTED WITH CERCOSPORA BETICOLA

One leaf spot is shown on the cotyledon at the left. (Photo by L. W. Brown, University of Wisconsin.)

planted with untreated seed, 33, 93, and 100 per cent of the plants were attacked by *C. beticola* with an average of 9, 79, and 604 spots per infected plant respectively. At the close of the season, only 18 and 38 per cent of the plants in the plots grown from treated seed showed any disease,

and these averaged 7.5 and 50.6 spots per infected plant, while 83, 100, and 100 per cent of the plants grown in the three plots from untreated seed were diseased having an average of 593, 1500 and 2195 spots per infected plant. Besides this the plants grown from the treated seed produced about three times as many leaves and roots by weight as those from the untreated seed and more than three times as much total sugar, although the percentage of sugar was practically the same from both treated and untreated seed.

It may therefore be concluded that heavily infected beet balls may be treated with formaldehyde, 15 to 1000 for seven minutes, without injury to germination or subsequent growth, and that the plants grown from such seed attain greater development and productivity on account of the control of the disease thus secured.

### *Stecklings*

The greatest source for the first infections of mother beets and subsequently of the beet balls is the infected crowns of the stecklings since *C. beticola* lives over the winter on the infected leaf blades and petioles that may remain attached to the stored roots. In the fall of 1912 normal sized roots with the heavily infected leaves left intact were placed in ground pits at Rocky Ford, Colorado. When the roots were examined the following spring, two spots out of ten tested gave growth of the fungus and the plants produced from these roots developed the disease early in the season. Other tests for the presence of *C. beticola* on stored stecklings were made in the spring of 1914 at Madison. Many of these stecklings had been treated with a solution of formaldehyde (commercial 40 per cent) 3 to 1000 for three minutes before being placed in storage the preceding fall. As previously shown in this paper a solution of this strength is not sufficiently strong to kill *C. beticola* in the infected tissues and cultures made from 30 spots taken from adhering petioles of these treated roots after five months in storage yielded 10 colonies of the fungus. Apparently the fungus was somewhat more vigorous in the diseased petioles of the untreated stecklings since approximately 200 colonies of the fungus developed in the cultures made from 24 spots of this material. The plants produced from these stecklings whether treated or untreated developed the disease early in the season and many of them became rosetted or were almost entirely defoliated late in August or early in September. The main stalks of such heavily diseased plants often showed a large number of distinct infected areas and occasionally some stalks were almost entirely covered with these lesions (fig. 1).

Before planting in the spring, some of the stecklings were treated with

a solution of formaldehyde 15 to 1000 for seven minutes. This treatment seriously injured the growth of the plants and is therefore impractical. Spraying the growing seed beets was attempted also but the spray could not be applied thoroughly enough to control the disease on account of the abundant production of small leaves and the falling over of the seed stalks.

As a further test of the control measures here described an effort was made to grow from sugar beet seed heavily infected with *C. beticola* a crop of seed as free as possible from this disease. Some of the practically disease-free first-year beets mentioned above as grown on rotated land and from home-grown, heavily infected, formaldehyde-treated seed, were carefully selected for the test. The leaves and most of the petioles were removed and the roots were packed in relatively dry, gravelly soil in boxes which were stored in a winter vegetable room where the temperature was held very close to 33°F. throughout the storage period as shown by records secured with a recording soil thermograph. The roots kept well, were planted in the spring on rotated land and developed, in general, vigorous healthy plants. In July a few typical leaf spots produced by *C. beticola* were found and the disease spread slowly as the season advanced but no appreciable leaf injury due to the disease was observed. The yield of seed secured was satisfactory in amount and of good quality and though it is probable that a few infections by *C. beticola* were present on some of the beet balls, the difference in the quality of the seed and its freedom from disease at the beginning and at the end of the two-year experiment was very striking.

By producing first-year beets or stecklings which are approximately free from disease and by using care in rotating the land and in isolating the mother beet fields so as to avoid infections from outside sources, the importance of which will be mentioned in detail below, the control of the disease on mother beets and therefore the avoidance of heavy infection of the beet seed, ought to be a very feasible commercial proposition.

### SPREAD AND CONTROL OF THE DISEASE THROUGH FEEDING BEET TOPS

Because of the value of beet tops for feeding purposes, many growers remove them from the fields after harvest. In order to determine whether such material when heavily infected with *C. beticola* could be used for feeding purposes with safety as to the spread of the disease the following season, experiments were conducted in feeding infected material direct to animals, in treating it with dry heat to approximate pulp dryer conditions, and in siloing the green tops immediately after harvest.

*Feeding infected beet tops to animals*

Three feeding experiments were conducted at Rocky Ford during the fall and early winter of 1912, the first two with three cattle (age seven years, three years, seven months) and one pig (age four months) and the third with two sheep (age three years, one year)—green tops from a heavily infected field being fed in the first experiment and dry tops in the second and third. During each experiment the amount of beet tops was gradually increased while other feed material was decreased until finally practically only beet tops were fed. The animals were carefully watched so that conditions as near normal as possible might be maintained. Dung was collected only after the animals had been fed from seven to thirteen days. Cultures were made direct from a few samples, one loop of the solid material being used as inoculum for each poured plate, then the dung from all samples was thoroughly mixed with sterilized water and cultures made by drawing off some of the liquid and plating, using from 0.05 to 0.4 cc. per plate. In some cases the material was kept over night, again thoroughly mixed, and a second set of cultures made from the liquid. No growth of *C. beticola* was obtained in any of the 277 cultures thus made. As a check on the feeding experiments two heavily infected beet tops were thoroughly ground in a food chopper and cultures were made from this material in the same way as those from the dung. Four loops of the solid material and 0.3 cc. of the liquid in ten plates yielded 26 colonies of *C. beticola*. Also check tests were made to determine the effect of diluted "old-manure" and "fresh-manure" decoctions on conidial germination and growth. In the tests with the former, normal growth occurred, but in those with the latter either no germination took place or only a very short and abnormal germ-tube was formed.

The results of these tests would seem to indicate that *C. beticola* is entirely killed in its passage through the alimentary tract of animals. Therefore the chief source of danger of returning the organism to the land in a viable condition through the feeding of beet top hay lies in the uneaten portions, which in ordinary feeding practices become mixed with the dung. Cultures made in January, 1913, from infected leaves and petioles which had been trampled into the manure in a feed lot in which beet top hay was being fed with other material, showed that the organism was viable in the infected areas of these uneaten portions.

*Effect of treating infected beet tops with dry heat*

In some countries where sugar beets are grown extensively, the green beet tops are sometimes removed from the fields directly after harvest,

dried in a pulp dryer and then fed to stock. In order to determine if the rapid drying of beet tops by heat would be effective in killing all portions of *C. beticola* present, some drying experiments were conducted (table 1) which indicated that *C. beticola* would be entirely killed in beet tops subjected to ordinary pulp dryer conditions, where the temperatures were slightly above those considered here to be effective in killing the fungus (100°C. for thirty minutes or 110°C. for fifteen minutes), and that

TABLE 1

*Effect of dry heat on the viability of Cercospora beticola in infected beet leaf tissue.*

| EXPOSURE | | NUMBER OF SPOTS USED FOR CULTURES | AVERAGE NUMBER OF COLONIES PER SPOT FROM | |
|---|---|---|---|---|
| Time | Temperature | | Air-dry leaves | Green leaves |
| | °C. | | | |
| Check..... | | 14 | 38.3 | |
| 15 minutes.... | 70 | 84 | 15.6 | |
| | 80 | 70 | 13 | |
| | 90 | 75 | 4 | |
| | 100 | 80 | 0.11 | |
| | 110 | 74 | 0 | |
| 30 minutes.... | 60 | 8 | 16.8 | |
| | 70 | 7 | 10.2 | |
| | 80 | 9 | 12.2 | |
| | 90 | 12 | 0 | 0.3 |
| | 100 | 12 | 0 | 0 |
| | 110 | 12 | 0 | 0 |
| | 120 | 12 | 0 | 0 |
| 60 minutes.... | 60 | 4 | 17.8 | 10.2 |
| | 70 | 6 | 7.1 | 1.5 |
| | 80 | 6 | 0 | 9.8 |
| | 90 | 14 | 0 | 2.7 |
| | 100 | 14 | 0 | 0 |
| | 110 | 14 | 0 | 0 |
| | 120 | 14 | 0 | 0 |

this material might then be fed without danger of returning the fungus to the soil in a viable condition.

*Effect of siloing beet tops on the fungus present*

The first experiments conducted by the writers to test the effect of siloing on the viability of *C. beticola* in infected beet tops was started in September, 1912, at Rocky Ford. A small, upright 3-ton silo was filled with alternate layers of freshly chopped beet tops and wheat straw, 19 pounds of common feeding salt being well mixed with the materials as it was placed in the silo and finally the material was tightly packed and

weighted. Plate cultures made from ten spots from the top portions and from ten taken from material eight inches below the surface, ten weeks after the silo was filled, and also from 60 spots taken from material 6 inches below the surface four months after the silo was filled, produced no growth of the fungus.

A second test to determine the effect of siloing was made with infected beet tops and oat straw put up in a 200-ton stave silo by the American Beet Sugar Company at Rocky Ford, in November, 1913, the test being carried on cooperatively. This silage consisted of six parts by weight of beet tops to one part of oat straw, no salt being used. Cultures made from 224 spots, three and one-half months after the material was siloed gave no growth of *C. beticola*.

During the summer of 1914 two laboratory tests were made at Madison to determine approximately, at least, the length of time *C. beticola* could withstand the siloing process. Infected green leaves fresh from the field and with a heavy production of conidia were packed firmly into jars having tight tops and a connecting glass tube leading into mercury to allow free escape of the accumulated gases. Eight and fifteen days after the material was thus siloed, portions of the infected tissue from 50 spots were placed in 18 culture plates, but no growth of *C. beticola* was secured. It thus appears from the standpoint of the control of the leaf spot disease that silage made from infected sugar beet tops could be fed in perfect safety two weeks after the silo was filled.

Negative results were also obtained in tests made to determine the ability of fresh cultures of the fungus to grow on artificial media made from beet top silage containing in one case 45 grams of silage, 55 cc. of water and 1.5 grams of agar, and in another case 45, 155, and 3.4 grams respectively of the three materials. Cultures on medium containing a still smaller proportion, that is 45, 355, and 7.4, produced slight growth of the fungus visible only after two weeks incubation, whereas check cultures made on string bean agar had during the same time entirely covered the surface of the medium.

## DISSEMINATION AGENTS

*The air.* Tests to determine the presence of viable conidia of *C. beticola* in the air were made during June, July, August and the first half of September, 1912, at Rocky Ford in several healthy and diseased sugar beet fields. Two hundred and ninety seven petri dish plates of bean agar were exposed near the ground in and near beet fields for different periods of time varying from a few minutes to half an hour. Most of the plates were exposed during the period from 7 o'clock in the morning

to 6 o'clock in the evening although a few were exposed as early as 4.30 o'clock and others as late as 10 o'clock. Cultures of the organism were obtained a number of times in the plates exposed in fields where the disease was present but never in those exposed at varying distances away from the infected fields or in fields not affected by the disease. Nine o'clock was the earliest and 4.40 o'clock p.m. the latest time of day when the organism was secured in the exposed plates; and the organism was obtained only when there was little or no possibility for condensed moisture as dew or rain drops on the leaves. During the months when the tests were made there were only about 5 inches of rainfall and these were at such infrequent intervals that there was small chance for the conidia to be washed out of the air for any considerable period of time.

These results would seem to indicate that viable conidia of *C. beticola* are carried about by the air in the diseased beet fields but that they would not be carried far away from such fields and still be able to germinate and produce infections. Field observations as shown below gave further evidence that the spores of the fungus generally travel only comparatively short distances from one field to another.

*Insects.* Tests were made to determine to what extent insects disseminate *C. beticola* by placing in culture plates different insects caught in diseased beet fields and allowing them to walk or move around for a few moments. One plate made in the early part of September with one "woolly bear" (*Diacrisia virginica* Fab.) produced 68 colonies of *C. beticola;* 46 alkali beetles and 8 larvae (*Monoxia puncticollis* Say.) produced only one colony; and 5 web worm moths (*Loxostege sticticallis* L.) as tested gave no growth of the fungus.

*Irrigation water.* In 1911, F. A. Wolf determined that conidia may be disseminated by irrigation water. (Unpublished note.) In tests made by the writers, four colonies of *C. beticola* developed in 89 cultures made from 41 cc. of irrigation water, or centrifuged sediment therefrom, secured while flowing through infected fields or standing in low portions of such fields. There remained the possibility, however, that many of the conidia present in the irrigation water would be killed by unfavorable conditions before they would have an opportunity to produce infections on other sugar beet plants.

## EFFECT OF ROTATION AND FIELD ISOLATION ON INFECTION

A study was made of approximately 1000 acres of sugar beets in the Arkansas Valley of Colorado during 1912 and 1913 to determine the effect of rotation on the first appearance and subsequent development of the leaf spot disease. In 1913 the first infections appeared in the greatest

number of the non-rotated fields on or before June 30 while the majority of the rotated fields showed their first infections on or after July 30. The fact that the disease appeared generally a month later in the rotated than in the non-rotated fields indicated that the infections in the former were not due to primary infections but rather to secondary ones from an outside source.

The influence of rotation as compared to non-rotation on the comparative progress of the disease was studied through the season and is illustrated by one rotated and five heavily infected non-rotated fields immediately adjoining it. The observations were made at intervals of two to six days and seven representative plants were studied in each field. When the first observations were made in the non-rotated fields on July 12, the spots found appeared to be about two weeks old. From this date until August 9 there was a gradual increase in number of spots per infected leaf from 5.9 to 48.2, and between this latter date and August 15 there was a decided increase to 217.7. The first spots in the rotated field were found July 26 which by August 15 had increased from 2.7 to only 86.4 spots per infected leaf. During the succeeding three weeks there was a rapid development of the disease in both rotated and non-rotated fields, the season's maximum average of 457.4 spots per infected leaf occurring September 10 in the rotated and of 412.5 on September 3 in the non-rotated fields. Although by the end of the season there was a greater amount of leaf spot present in the rotated than in the non-rotated fields, a greater number of functional leaves were present and fewer leaves were killed by *C. beticola* during the season in the former because of the late attack. Moreover on account of the larger size of the plants in the rotated field throughout the season there was proportionally less leaf spot to leaf area than in the non-rotated field.

A study was also made of the amount of leaf spot present at different distances in from the edge of rotated fields adjoining non-rotated, these fields being separated by a small irrigation ditch or a few feet of fallow ground, to determine the distance over which the fungus may spread and the separation that must be made between fields to insure a definite degree of isolation. The observations were made in the first part of September, 1913, the data being collected on the same date from the two fields in each series. In the first series the amount of leaf spot at a distance of 12 yards into the rotated field was approximately the same as in the non-rotated field, at 55 yards about one-fourth as much, at 100 yards one-eighth, and at 200 yards one-seventeenth; in a second series at a distance of 3 yards into the rotated field the amount was about one-sixth and at 63 yards one-twenty-eighth as much as in the non-rotated field; in a third series there was a greater number of spots per infected

leaf at 50 yards in the rotated field than in the non-rotated yet only one-fifth as many leaves had been killed, while at 100 yards there was one-twelfth as many leaves killed; in a fourth series at a distance of 30 yards into the rotated field there was one-fifth as much disease as in the non-rotated field and at a distance of 100 yards the amount was only slightly further decreased but at the latter distance no leaves were killed as compared to 4.6 leaves per plant at 30 yards and 6.3 in the non-rotated field.

Finally in determining the effect of isolating the rotated fields from other non-rotated fields which were usually heavily infected, comparative data were collected in a field of each type on September 19. The amount of disease found in the rotated and isolated field, which was about 300 yards from any other beet field, was only one-sixth as much (55 spots per infected leaf) as in the rotated and non-isolated field (376.3) and one-ninth of that in the non-rotated field (490.1). Moreover, no leaves were killed in the first-named field, while 20 and 17.3 leaves per plant, respectively, were killed in the other two.

These studies, accompanied by other field observations, indicate, therefore, that rotation without field isolation delays the first appearance of infection in such fields but does not necessarily lessen the amount of disease which may develop in them by the end of the season. On the other hand, rotation combined with field isolation in which the rotated fields are at least 100 yards from any non-rotated fields generally gives adequate control of the disease.

### EFFECT OF THE DISEASE ON THE BEET PLANT

A study of the effect of leaf spot infection on sugar production by the beet plant was made by the American Beet Sugar Company during the growing season of 1910 by means of chemical analyses of affected beets made at intervals of two weeks. The data secured (table 2) have been made available to the writers for consideration in connection with their investigations.

Frank[8] in 1897, from a few tests of beet roots from plants heavily infected with *C. beticola*, found that the final loss from the disease was in the weight of the beet root and not in the percentage of sugar. This appears to be substantiated, in general, by the analyses here reported, but the first decrease in weight was found to occur in the leaves. The beet plant, it would seem, maintains a uniform percentage of sugar, though the total amount of sugar and the weight of the root may be reduced by disease. From July 18 to August 1, as shown by the data, the percent-

[8] Frank, A. B. Neuere Beobachtungen über die Blattfleckenkrankheit der Rüben (*Cercospora beticola*). Zeitsch. Ver. Rübenzuckerindus. Deut. Reichs. **47:** (n. F. Jahrg. 34) Tech. T.: 589–597, *pl. 8.* 1897.

age of sugar remained constant, and the increase in weight of roots, leaves and the total amount of sugar was greatest. From August 1 to 15, about 25 per cent of the leaves were destroyed by the fungus, and the greatest loss in the plant during that time was in the weight of the leaves, this being closely followed by diminished increase in the weight of roots, but there was a slight increase in the percentage of sugar and total sugar. From August 15 to September 5, about 90 per cent of the leaves were

TABLE 2

*Effect of leaf spot infection on the beet plant as shown by chemical analyses.*

| Date of taking sample | Weight in grams | | | | | | Per cent sugar | |
|---|---|---|---|---|---|---|---|---|
| | Leaves of average plant | Increase or decrease since last test | Root of average plant | Increase or decrease since last test | Sugar in root of average plant | Increase or decrease since last test | Root of average plant | Increase or decrease since last test |
| 1910 | | | | | | | | |
| June 6 | 12.1 | | 2.03 | | 0.8 | | 3.8 | |
| June 20 | 93.0 | + 80.9 | 31.0 | + 28.97 | 2.3 | + 1.5 | 7.4 | +3.6 |
| July 5 | 260.6 | +167.6 | 143.3 | +112.3 | 11.7 | + 9.4 | 8.2 | +0.8 |
| July 18 | 412.7 | +152.1 | 379.3 | +236.0 | 44.0 | +32.3 | 11.6 | +3.4 |
| Aug. 1 | 700.6 | +287.9 | 761.9 | +382.6 | 88.4 | +44.4 | 11.6 | 0 |
| Aug 15[1] | 551.3 | −149.3 | 830.4 | + 68.5 | 107.0 | +18.6 | 12.9 | +1.3 |
| Sept. 5[2] | 186.3 | −365.0 | 860.2 | + 29.8 | 123.5 | +16.5 | 14.4 | +1.5 |
| Sept. 19 | 162.5 | − 23.8 | 1032.0 | +171.8 | 112.5 | −11.0 | 10.9 | −3.5 |
| Oct. 3 | 206.9 | + 44.4 | 1039.1 | + 7.1 | 134.0 | +21.5 | 12.9 | +2.0 |
| Oct. 11 | 103.7 | −103.2 | 892.8 | −146.3 | 126.5 | − 7.5 | 14.2 | +1.3 |

[1] From August 1–15 about 25 per cent of the leaves were destroyed by leaf spot.

[2] From August 15 to September 5, 90 per cent of the leaves were destroyed by leaf spot.

destroyed by the fungus, and during this time the weight of the leaves continued to decrease and the root had a still further diminished increase. During the remainder of September the extreme leafs pot infection gradually subsided and the plants began to recuperate, but during that time the total sugar decreased, although the weight of the roots increased perceptibly. The greatest weight of roots and of total sugar in the roots occurred October 3, but after this there was an actual decrease in both, while the percentage of sugar returned to what it had been four weeks earlier.

## SUMMARY

1. *Cercospora beticola* Sacc. produces leaf spots on sugar beets, red garden beets, Swiss Chard, mangel-wurzel, and *Martynia louisiana* Mill., a weed commonly known as double claw or Devil's claw, the last plant mentioned being the only new host found by the writers.

2. The first or primary leaf spot infections on sugar beets may come from infected beet balls or the débris of other hosts than the sugar beet, but chiefly from the old beet top material left on the ground after harvest the preceding season.

3. Careful removal of infected beet tops after harvest delays the appearance of the disease in non-rotated fields the following season and greatly reduces the injury therefrom.

4. Foreign grown sugar beet seed received in this country during the last few years showed no infection on the samples examined, but some American grown seed showed numerous heavy infections.

5. Treatment of infected beet seed with formaldehyde (commercial 40 per cent) 15 to 1000 for seven minutes kills *C. beticola* without injuring the germination of the seed, and plants grown from seed thus treated attain greater development and productivity than do those from untreated infected seed.

6. *Cercospora beticola* in beet tops fed to animals is apparently entirely killed in its passage through the alimentary canal and is also killed when the infected beet tops are subjected to a temperature of 100°C. for thirty minutes or 110°C. for fifteen minutes. However, the greatest danger of spreading the disease through feeding beet tops without previous treatment exists in the uneaten portions which become mixed with the manure. The best method for preventing the spread of the disease through feeding practices is to remove and store the green beet tops in a silo since the organism does not survive the silage process for even two weeks.

7. The organism is spread to some extent by the air, insects, and irrigation water.

8. Sugar beet fields should not only be rotated but also separated from non-rotated beet fields by at least 100 yards to avoid in great measure the spread of the disease from one field to another.

OREGON AGRICULTURAL EXPERIMENT STATION
CORVALLIS, OREGON.

## PHYTOPATHOLOGICAL NOTES

*Personals.* Mr. R. D. Rands, lately of Columbia University, has been appointed as field assistant in cereal pathology, Bureau of Plant Industry.

Mr. A. L. Wilson of the Utah Agricultural College has accepted a position as agent in pathology for the Bureau of Plant Industry and is engaged in the control of truck crop diseases in the State of Utah.

Dr. Royal J. Haskell, formerly assistant professor of plant pathology in the New York State College of Agriculture, Ithaca, New York, accepted a position with the Plant Disease Survey and began his new duties July 20, 1917.

Mr. J. H. Muncie, research assistant in plant pathology at the Michigan Agricultural Experiment Station, East Lansing, Michigan, has recently been appointed pathological inspector with the Plant Disease Survey.

Dr. C. H. Kauffman of the University of Michigan began his work as a pathological inspector with the Federal Horticultural Board September 16, 1917.

Prof. A. H. Gilbert of the University of Kentucky, who spent the summer in the employ of the Office of Cotton, Truck, and Forage Crop Disease Investigations, has accepted a position as a pathological inspector with the Federal Horticultural Board.

Mr. C. C. Thomas of Cornell University began his work January 1, 1918, as assistant in plant disinfection in the office of the pathological inspector of the Federal Horticultural Board.

Dr. Wm. H. Weston has been transferred from his position as pathological inspector with the Federal Horticultural Board to the Bureau of Plant Industry, to investigate, in the Orient, the downy mildews of corn due to species of Sclerospora and Peronospora. He sailed for the Philippines January 5, 1918.

Mr. G. W. Martin and Mr. John Montieth have received commissions as First Lieutenant and Second Lieutenant, respectively, in the Officers' Reserve Corps and have been called to active service in the National Army.

Mr. Ned W. Lacey, formerly with the Plant Disease Survey, has completed the Princeton Ground School of the Aviation Section of the Signal Corps and is now abroad with the American Expeditionary Force.

Prof. L. E. Melchers of the Department of Botany at the Kansas State Agricultural College is acting head of the Department of Botany and Plant Pathology for the year 1917–1918, being in charge during the leave of absence of Prof. H. F. Roberts.

Mr. H. H. Haymaker, recently a graduate student at the University of Wisconsin, has accepted a position as instructor in the department of botany at the Kansas State Agricultural College. Mr. Haymaker entered the Bureau of Plant Industry in May, 1917, and was stationed at Greeley, Colorado, in potato disease work. He is now an instructor in plant pathology at Manhattan, Kansas.

## LITERATURE ON PLANT DISEASES[1]

COMPILED BY EUNICE R. OBERLY, LIBRARIAN, BUREAU OF PLANT INDUSTRY, AND FLORENCE P. SMITH, ASSISTANT

### December, 1917

**American Phytopathological Society. Cereal Pathologists.** [Third annual] field conference of cereal pathologists. Phytopathology **7**: 453–454. D. 1917.
A more complete account of this meeting has been published in Science n. s. **46**: 316–318. S. 28, 1917.

**Biffen, Rowland Harry.** Report of the consulting botanist, 1916. Jour. Agr. Soc. England **77**: 217–222. 1917.
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**Bisby, G. R.** The Uredinales found upon the Onagraceæ. Amer. Jour. Bot. **3**: 527–561. D. 1916.

**Burt, Edward Angus.** Merulius in North America. Ann. Missouri Bot. Gard. **4**: 305–362, illus., pl. 20–22. N. 1917.
Issued D. 8.

**Castella, F. de,** and **Brittlebank, C. C.** Notes on downy mildew (Plasmopara viticola, B. & de T.). Jour. Dept. Agr. Victoria **15**: 685–700, 2 fig. N. 10, 1917.

**Christensen, C. J.** Tiltraekning af kaalroeformer med saerlig modstandsevne mod kaalbroksvamp. Tidsskr. Planteavl. **24**: 68–82. 1917.

**Elliott, John Asbury.** The conduction of potassium cyanide in plants. Phytopathology **7**: 443–448, 2 fig. D. 1917.

**Eriksson, Jakob.** Développement primaire du mildiou (Phytophthora infestans) au cours de la végétation de la pomme de terre. Rev. Gen. Bot. **29**: 305–320. S. 1917.
Mémoire présenté à l'Académie royale des sciences de Suède à l'occasion de la fin de la présidence, le 12 avril 1916. Traduit suédois par Mme. Signe Hagman.

**Fromme, Fred Denton.** Tylenchus tritici on wheat in Virginia. Phytopathology **7**: 452–453, 1 fig. D. 1917.

**Gilbert, Albert Holley** and **Bennett, C. W.** Sclerotinia trifoliorum, the cause of stem rot of clovers and alfalfa. Phytopathology **7**: 432–442, 5 fig. D. 1917.
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[1] This list includes references, both American and foreign, to the literature of plant pathology and mycology of interest to pathologists. Foreign references published since January 1, 1917, have been included beginning with the list appearing in v. 7, no. 3, June, 1917.

All authors are urged to coöperate in making the list complete by sending their separates and by making corrections and additions, and especially by calling attention to meritorious articles published outside of regular journals. Reprints or correspondence should be addressed to Miss E. R. Oberly, Librarian, Bureau of Plant Industry, U. S. Dept. Agri., Washington, D. C.

**Great Britain. Board of Agriculture and Fisheries.** Wart disease of potatoes: reports on the immunity trials at Ormskirk in 1915–16–17. Jour. Bd. Agr. Gt. Brit. **24:** 801–818, pl. N. 1917.

**Güssow, Hans Theodor.** The occurrence of Colletotrichum cereale, Dothichizia populea, and Leptosphæria napi in Canada. Phytopathology **7:** 450. D. 1917.

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**Harter, Leonard Lee.** Podblight of the lima bean caused by Diaporthe phaseolorum. Jour. Agr. Research **11:** 473–504, 11 fig., pl. 42–43. D. 3, 1917.
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**Jackson, Herbert Spencer.** Apple diseases in Indiana, with spray schedule. Indiana Agr. Expt. Sta. Circ. 70, 23 p., 14 fig. 1917.

**Jones, Lewis Ralph, Johnson, Aaron Guy,** and **Reddy, C. S.** Bacterial-blight of barley. Jour. Agr. Research **11:** 625–643, 2 fig., pl. B, 47–49. D. 17, 1917.
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**McMurran, Stockton Moseby.** Walnut blight in the eastern United States. U. S. Dept. Agr. Bul. 611, 7 p., 2 pl. 1917.

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**Nowell, William.** Report of the mycologist of the department [Imperial Department of Agriculture for the West Indies, 1916/17]. Agr. News [Barbados] **16:** 334–335, 350–351. O. 20, N. 3, 1917.
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**Orton, William Allen.** Watermelon diseases. U. S. Dept. Agr. Farmers' Bul. 821, 18 p., 11 fig. 1917.

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**Petch, Thomas.** Quarterly progress report of the botanist and mycologist [Ceylon]. Trop. Agr. [Ceylon] **49:** 175. S. 1917.
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**Potter, Michael C.** Economic mycology. Jour. Roy. Hort. Soc. [London] **7:** 317–323. S. 1917.
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**Reddick, Donald.** Effect of soil temperature on the growth of bean plants and on their susceptibility to a root parasite. Amer. Jour. Bot. **4:** 513–519. N. 1917.

**Reed, George Matthew.** The discovery of Endophyllum sempervivi (Alb. & Schw. deBary) in North America. Torreya **17:** 84–85. My. 1917.

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**Stewart, Vern Bonham.** The perennation of Cronartium ribicola Fisch. on currant. Phytopathology **7:** 449–450. D. 1917.

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**Trumbull, H. L.,** and **Hotson, J. W.** The effect of Roentgen and ultraviolet rays upon fungi. Phytopathology **7:** 426–431, 2 fig. D. 1917.

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